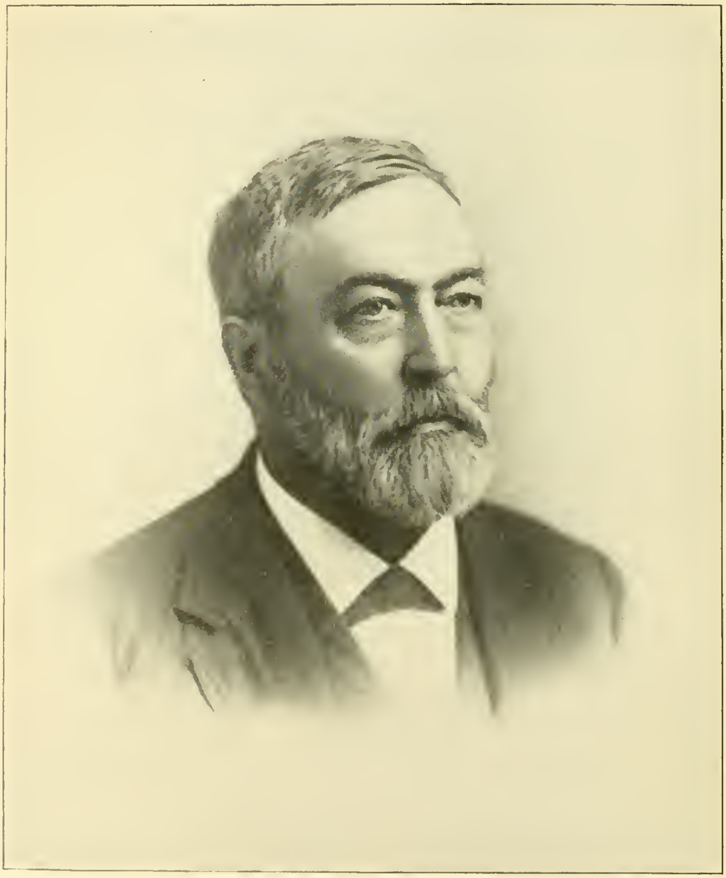


COLONEL HENRY FLAD.

President Engineers' Club of St. Louis, 1868-1880.

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST LOUIS.
MONTANA. ST. PAUL. DETROIT. PACIFIC COAST.
BUFFALO. LOUISIANA. CINCINNATI.

CONTENTS AND INDEX.

VOLUME XXII.

January to June, 1899.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOHN C. TRAUTWINE, JR., *Secretary*, 257 S. FOURTH STREET, PHILADELPHIA.

CONTENTS.

VOL. XXII, January-June, 1899.

For alphabetical index, see page v.

No. 1. JANUARY.

No. 4. APRIL.

No. 5. MAY.

No. 6. JUNE.

INDEX.

VOL. XXII, January-June, 1899.

The six numbers were dated as follows:

No. 1, January.	No. 3, March.	No. 5, May.
No. 2, February.	No. 4, April.	No. 6. June.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

PAGE

Association of Engineering Societies.

Organized 1881.

Vol. XXII. JANUARY, 1899. No. 1.

COMPARATIVE TESTS ON DIFFERENT FORMS OF CEMENT BRIQUETTES.

By Prof. Jerome Sondericker, Member of the Boston Society of Civil Engineers.

[Read before the Society December 21, 1898.*]

The circular recently issued by the Committee of the American Society of Civil Engineers on Tests of Cement reopens questions concerning the relative merits of different forms of briquette, distance between bearing points and the like. In order to secure more definite information in these directions Mr. Henry C. Belcher, Class of 1898, M. I. T., undertook for his graduating thesis to make comparative tests on different forms of briquette. The thesis included the selection of the forms of briquette to be tested, the design of special clips for the tests and the tests themselves. The forms of briquette selected are shown in Fig. 1. In A the dotted lines indicate the form in use at M. I. T. This form was elongated in order to secure a length between gripping points up to 3 inches. Both are included under the letter A. B is similar to A, but with more flaring sides, the slope of the tangents being 1½ to 1. It differs from the form suggested by Mr. L. C. Sabin (see *Municipal Engineering*, February, 1897, p. 77) only in the radius at the center being 1 inch instead of ¾ inch. It is also elongated. C is a modification of the German standard, which is shown in Fig. 2 for comparison. The section was altered to 1 square inch, and it was made of the same length as A and B. C is also similar to a form understood to have been proposed by Prof. J. B. Johnson. D is the A. S. C. E. standard form.

*Manuscript received December 29, 1898.—Secretary, Ass'n of Eng. Socs.

Fig. 3 is a drawing of the clips, also taken from Mr. Belcher's thesis. Double knife edges were used to secure a central pull. These are not shown in the drawing. The side guides are used to hold the clips in position while inserting the briquette. This device was described in my paper on cement testing published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for June, 1888; also in the "Transactions of the American Society of Mechanical Engineers," Vol. IX. The rounded gripping points

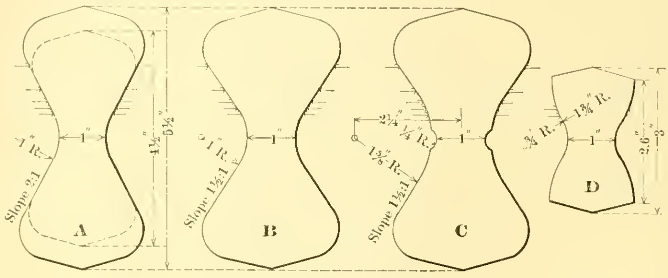


Fig. 1. Scale 1=4

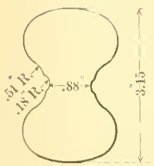


Fig. 2.
Scale 1=4

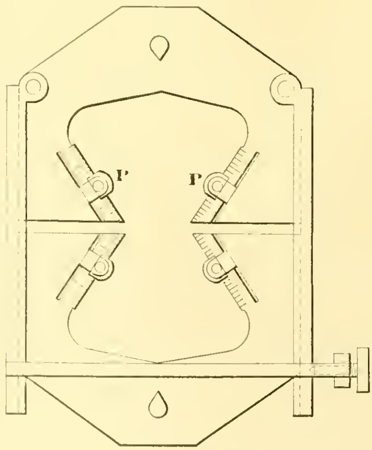


Fig. 3.

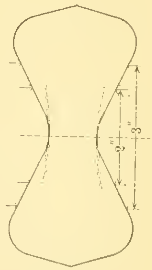


Fig. 4.
Scale 1=4

have radii of 9-32 and $2\frac{1}{2}$ inches respectively, parallel and at right angles to the face of the clips. These points slide on the inner surfaces of the clips, and can be set in any position by means of the graduations. They are held in place by springs on each side, engaging the grooves shown in the drawing. With this arrangement all the forms of briquette could be broken, and the length between gripping points varied from 1 to 3 inches. The length of specimen always means the distance between the gripping points of the two clips, and not the distance between the gripping points

of the same clips, which will be referred to as the width between gripping points. These widths for different lengths of specimen are given in Table I.

TABLE I.

Length of Specimen.	Width between Gripping Points.			
	A	B	C	D
1″	1.26″	1.27″	1.41″	1.36″
1¼″	1.39″	1.43″	1.50″	1 48″
1½″	1.51″	1.59″	1.62″	
2″	1.76″	1.93″	1.93″	
3″	2.26″	2.59″	2.59″	

The moulds used were divided into sets of four, and included three sets of A (short), one set of A (long) and one set each of B, C and D, twenty-eight moulds altogether.

The general plan was to fill all the moulds with one mixing and break all the briquettes of any one mixing at the same time. In testing each of the larger sets the four briquettes were broken with different lengths of specimen, namely, 1, 1½, 2 and 3 inches. In each of the short A sets the lengths were 1, 1¼, 1½ and 2 inches. In each of the D sets the lengths were 1 and 1¼ inches (two briquettes each). These lengths are shown in Fig. 1. We had thus the means for determining the variation of strength with length of specimen for each form of briquette, and also the relative strength of the different forms. Mr. Belcher's time permitted his testing only a small number of briquettes, and the results obtained were not conclusive. For this reason I undertook experiments under the plans outlined above. The results will now be presented.

Four hundred and eighty-eight briquettes were broken, including Portland cement, neat and three parts sand to one cement; and Rosendale cement, neat and one part sand to one cement. Part of these were broken after about one week, and the remainder after about four months.

I. VARIATION OF STRENGTH WITH LENGTH OF SPECIMEN BETWEEN GRIPPING POINTS.

To determine this the breaking strengths of the individual briquettes in each set of four were expressed in percentages, calling the strength of the one broken with a length of 1 inch 100. The average of these percentages was then taken in various ways, as indicated in the first column of Table II, where the results are recorded. The figures in parenthesis are the number of tests averaged, and will give an indication of the reliability of the aver-

ages. Although some of the briquettes were obviously imperfect, all are included in these averages with the exception of five which broke by a corner of the head shearing off.

From the results given in Table II it would seem that for neat cement briquettes the tensile strength increases with the length of specimen, the rate of increase being shown in the second line of the table. The results for both long and short time tests, Portland and Rosendale cement, and for each of the different forms of briquette, agree with this conclusion.

TABLE II.

Comparative tensile strength of briquettes broken with different lengths between gripping points. Strength for 1-inch length, 100.

Tests Averaged.	Length between Gripping Points.			
	1¼″	1½″	2″	3″
All	107 (61)	108 (97)	112 (104)	118 (60)
All neat cement	108 (50)	110 (78)	115 (84)	123 (50)
Neat Portland, 1 week old	110 (19)	111 (30)	118 (31)	122 (17)
Neat Portland, 4 months old	102 (8)	112 (12)	111 (12)	126 (6)
All neat Portland	108 (27)	111 (42)	116 (43)	123 (23)
Neat Rosendale, 1 week old	110 (15)	109 (25)	113 (29)	123 (21)
Neat Rosendale, 4 months old	106 (8)	106 (11)	113 (12)	124 (6)
All neat Rosendale	108 (23)	108 (36)	113 (41)	123 (27)
Forms A (long), B, C, neat	....	111 (50)	114 (50)	123 (50)
Form A (short), neat	108 (34)	108 (34)	117 (34)	....
Form A (long), neat	....	110 (16)	115 (16)	121 (16)
Form B, neat	....	113 (16)	108 (16)	127 (16)
Form C, neat	....	109 (17)	113 (17)	116 (17)
Form D, neat	107 (16)	....	....	....
All sand mortars	103 (11)	103 (19)	101 (20)	95 (10)
All 3 sand, 1 cement, Portland	105 (3)	98 (8)	102 (8)	101 (4)
All 1 sand, 1 cement, Rosendale	102 (8)	106 (11)	101 (12)	90 (6)
Forms A (long), B, C, sand mortars	....	96 (11)	95 (11)	95 (11)
Form A (short), sand mortars	103 (8)	112 (2)	111 (8)	....
Form A (long), sand mortars	....	100 (4)	90 (4)	99 (4)
Form B, sand mortars	....	89 (3)	100 (3)	96 (3)
Form C, sand mortars	....	96 (4)	94 (4)	91 (4)
Form D, sand mortars	104 (4)	....	....	....

In case of the sand mortars tested the strength appears to be nearly independent of the length of specimen. A greater number of tests are needed to confirm this result.

II. RELATIVE STRENGTH OF DIFFERENT FORMS OF BRIQUETTE.

The strengths of the different forms of briquette were compared, making the comparison only between briquettes having the same length between gripping points. For this purpose Form A was taken as standard, and the strengths of the other forms for any one mixing expressed in per cent. of the strength of A. The

average results obtained by this comparison are given in Table III. As in Table II, the sand mortars are the average of a comparatively small number of tests. From Table III it appears that, for the same length of specimen, A, B and D give about the same strength, B falling a trifle below A and D. The results for B are also somewhat irregular. C gives uniformly a lower strength than the others—about 13 per cent. on the average. This conclusion is true for neat cement, and, with the exception of B, for sand mortars. The averages for each distance between gripping points agree with the general averages given in the first line of Table III. These separate averages are given in Table IV.

TABLE III.

Comparative strength of different forms of briquette.

Tests Averaged.	A	B	C	D
All	100	98.4	87.0	100.0
All neat cement	100	100.6	87.2	98.9
Portland, 1 week old, neat	100	98.8	83 9	101.2
Portland, 4 months old, neat	100	99.3	91.0	102.9
Rosendale, 1 week old, neat	100	105.6	90.1	96.0
Rosendale, 4 months old, neat	100	89.2	84.0	94.6
All sand mortars	100	88.6	86.2	104.8
Portland, sand 3, cement 1	100	92.5	89.8	100.3
Rosendale, sand 1, cement 1	100	85.2	83.0	108.2

TABLE IV.

Comparative strength of different forms of briquette for each length of specimen between gripping points.

	Length between Gripping Points.				
	1″	1¼″	1½″	2″	3″
Form A	100	100	100	100	100
Form B	98.9	....	96.3	94 0	105.2
Form C.	89.6	....	87.7	87.5	83.3
Form D	100.6	99.4	....	....	....

III. PERCENTAGE OF FRACTURES NOT AT SMALLEST SECTION.

The areas of the sections at which the fractures occurred were determined in order to make a comparison between the different forms of briquette and different lengths of specimens in this respect. For this purpose the fractures were grouped into those where the fractured area exceeded the area of the smallest section (1 square inch) by the following amounts: 1 by less than 5 per cent.; 2 between 5 and 10 per cent.; 3 by more than 10

per cent. The percentage of fractures for each length of specimen falling within these limits is given in Table V. In Form C all the briquettes broke within the notch, but not at its center. The section at the edge of the notch is 1.25 inch. As only two bri-

TABLE V.

Percentage of fractures falling within the limits stated in first column.

Excess of Area.	Form.	Length between Gripping Points. 1″	1¼″	1½″	2″	3″
Less than 5 per cent.	A	90.5	83.4	85.0	75.8	85.0
	B	90.0	......	93.7	76.2	78.9
	C	95.2	......	100.0	85.7	95.2
	D	95.0	72.3	......	......	......
Between 5 per cent. and 10 per cent.	A	4.8	14.3	11.7	17.7	10.0
	B	10.0	......	6.3	14.3	10.5
	C	4.8	......	0	9.5	4.8
	D	5.0	16.7	......	......	......
Above 10 per cent.	A	4.8	2.4	3.3	6.4	5.0
	B	0	......	0	9.5	10.5
	C	0	......	0	4.8	0
	D	0	11.1	......	......	......

quettes of the other forms broke where the area was greater than 1.25 inch, the behavior of C in this respect is not remarkable. The notch, however, would explain the somewhat higher percentage of center fractures for this form.

From Table V we conclude that the number of fractures away from the smallest section is not influenced materially by the length of specimen, and is about the same for Forms A, B and D. If we compare the different forms of briquette without reference to the length of specimen we find the following percentages of fractures at sections where the excess of area is less than 5 per cent: A, 83.9 per cent.; B, 84.2 per cent.; C, 94.0 per cent.; D, 84.3 per cent.

A similar comparison for sand mortars alone gives the following results: A, 91.1 per cent.; B, 100 per cent.; C, 100 per cent.; D, 92.9 per cent.

Of the eighty-nine sand mortar briquettes only five broke where the excess of area was 5 per cent. or more, the greatest excess being 6.8 per cent. Although the gripping points were quite sharply rounded, out of the total of 488 briquettes broken only two broke at the gripping points; these two were of Form A, with 1 inch length between gripping points. Five broke by shear-

ing off a corner of the head, namely, three D's, $1\frac{1}{4}$-inch length; one A, 3-inch length, and one B, 3-inch length. This discussion has no reference to clip breaks. With properly designed moulds and clips there should be no breaks at the gripping points.

IV. RELATION BETWEEN POSITION OF FRACTURE AND STRENGTH OF BRIQUETTE.

The breaking strengths of each set of four briquettes were graded, calling the lowest one and the highest four. Of the sixty-five briquettes which broke outside the 5 per cent. limit, there were eleven ones, fourteen twos, sixteen threes and twenty-four fours. This shows that the strongest briquettes are most likely to break out of the smallest section. Of the five sand mortar briquettes which broke beyond the 5 per cent. limit, there were two ones, one two and two fours.

V. CAUSE OF NON-CENTRAL FRACTURES, AND THEIR CONNECTION WITH THE FORM OF THE BRIQUETTE.

In order to discuss this matter refer to the second line of Table II. The strength for 1 inch length is 100. Let us take this to represent, roughly, the strength per square inch of a briquette at a point $\frac{1}{2}$ inch from the gripping points. Similarly take 108 to represent the strength per square inch at $\frac{5}{8}$ inch from the gripping points, etc. If now the length of specimen is 3 inches, the numbers 100, 108, 110, 115 and 123 may be taken to represent roughly the relative strength per square inch at distances of $\frac{1}{2}$ inch, $\frac{5}{8}$ inch, $\frac{3}{4}$ inch, 1 inch and $1\frac{1}{2}$ inches from the gripping points. In order for the briquette to be equally liable to break at these different sections, then, the areas of these sections must be inversely proportional to the relative strengths stated above. For example, in the case assumed the width of the briquette at a point $\frac{1}{2}$ inch distance from the gripping points would have to be 1.23 inches in order for the briquette to be equally liable to break at this point and at the middle. In this manner the widths at different distances from the gripping points, necessary in order that a briquette of neat cement would be equally liable to break at all sections, were calculated. The results for lengths between gripping points of 2 and 3 inches are plotted in Fig. 4. The longer curve corresponds to the 3-inch length. These curves would then represent the outline of a briquette of equal strength for the lengths between gripping points stated. Form A is drawn for comparison. From this diagram it appears probable that the excess of strength for sections near the middle is very small. Take the 2-inch length,

for example. At $\frac{1}{4}$ inch from the smallest section the width of the briquette is 1.06 inches, and the width necessary for equal strength is 1.045 inches, so there is an excess of width at this point of .015 inch. At $\frac{1}{2}$ inch distance the width of the briquette is 1.26 inches, and the width necessary for equal strength 1.15 inches, leaving an excess of width of .11 inch. Of the eighty-two briquettes of Forms A and B (B near the middle has the same outline as A) broken with a length of 2 inches, sixty-six broke within $\frac{1}{4}$ inch of the middle, —*i.e.*, where the excess of section over that necessary for equal strength, according to the above estimate, was less than .015 inch; and the remaining sixteen briquettes broke where the excess of section was .12 inch or less. The non-central fractures in this case would then be accounted for by the inevitable slight variations of strength at different points in the same briquette, and they could be prevented only by taking the utmost pains in moulding.

Of the 488 briquettes broken only 89 were sand mortars. A separate comparison of these is of some interest, but the results would need to be confirmed by a greater number of tests. It is seen by Table II that, while the strength of the neat cement briquettes increased with the length between gripping points, the sand mortars showed about the same strength for all lengths, so that in their case the excess of strength at different sections would be about the same as the excess of section over 1 square inch. From this greater excess of strength, as compared with neat cement briquettes, we would expect the sand mortars to be less likely to break non-centrally than the neat cement, and this is the case. Of the eighty-nine sand briquettes only five broke outside the 5 per cent. limit of area excess over 1 square inch, and of these five the greatest excess of section at point of fracture was 6.8 per cent. This discussion is only given as a suggestion. It would account for the non-central fractures corresponding to the strongest briquettes.

VI. REMARKS.

Let us now refer briefly to the conditions which should be considered in connection with standard methods of testing cement in tension, as far as moulds and clips are concerned.

1. The strength varies with the form of briquette. There are two general forms, the notched form represented by the German standard and the form with gradually sloping sides represented by A, B and D. In the former the fracture is invariably within the notch, but there is also a reduction of strength of about 13 per cent. as compared with the latter. I do not see any advantage in securing a center fracture by a notch. As the form with-

out a notch appears to be more sensitive to unfavorable conditions, it seems to me to be the more desirable of the two. There is no special value in always securing a center fracture. The ideal briquette in this respect would be one which would break centrally if it was carefully moulded and properly tested, but which would be likely to break out of center if this work was not properly done.

2. We have seen that the strength, at least for neat cement, varies to a marked degree with the length between gripping points. This length should then be fixed, and, for convenience, should be comparatively short.

3. The strength and general behavior of the briquette when tested varies with the kind of bearing points. Mr. L. C. Sabin (see *Municipal Engineering*, 1896-97) found that with rubber cushions interposed between the clips and briquette the strength was reduced 10 or 15 per cent. He found that using the Riehlé clips without rubber, with a width of specimen at gripping points of $1\frac{1}{4}$ inches, about 30 or 40 per cent of the specimens broke at the gripping points. With substantially the same distance between gripping points, 1.26 inches, I obtained only two clip breaks altogether. With a greater width at gripping points Mr. Sabin still obtained a few clip breaks, while I obtained none under similar conditions. We must conclude that the bearing points affect the results. The rubber bearings are objectionable from the destructible character of the material. If they secure center fractures invariably, accompanied by a reduction of strength, the notched form accomplishes the same result without the use of rubber. Then, again, center fractures in themselves are of little consequence unless they serve to indicate that the work of moulding and testing has been properly done. Cement clips should be simple in construction, with as few joints to get out of order as possible. For this reason sliding or pivoted points should be ruled out, unless they give better results than the solid bearing. To be brief, it is my opinion that solid, hard metal gripping points, properly rounded in both directions so as to touch at the middle of the thickness of the briquette, are the most desirable. In any case, standard bearing points should be settled upon both as to material and curvature.

4. The other point to consider in this connection is the means for adjusting the briquette in position in the clips. Every one will agree that the pull should be central,—*i.e.*, along the axis of the briquette. In the ordinary clips we hang the specimen from the upper clip, hang the lower clip on the specimen and depend on our sight and touch to get all three in proper relative position.

The desirable thing is to have the two clips held mechanically in proper relative position, so that when the briquette is inserted and brought to a bearing the axis of the briquette will coincide with the line joining the pivots and the face of the briquette be parallel to the faces of the two clips.

A second consideration is that the four bearing points must lie in the same plane with the pivots, otherwise a bending action will occur, the clips swinging or tending to swing about the bearing points. This action is liable to occur if the clips touch over the whole width of the briquette, and can best be provided against by rounding the points in both directions.

The desirable conditions in this direction are, therefore, that the clips should be held in proper relative position so that when the briquette is inserted and brought to a bearing the axis of the briquette will coincide with the line joining the pivots, and the four gripping points will each touch the briquette in the middle of its thickness. Under these conditions the pull will be central and remain so, and no bending action will occur.

The clips designed at the Institute of Technology to secure these conditions have been described in a previous paper (see Journal of the Association of Engineering Societies, June, 1888). They have been in use ever since, and have given satisfaction. They could, doubtless, be improved in details. It is a question in my mind as to whether conical pivots would not be better than double knife edges. They would be simpler and answer the same purpose, if properly made of hardened steel. The special feature of the design, the side guides, have served their purpose fully.

From this discussion, then, it seems that in order to secure comparable results (this being the object of standard methods of testing cement in tension) it is necessary to fix the form of briquette, the length between gripping points and the form of the gripping points. It would also appear to be desirable for the committee to investigate the subject of mechanical means for securing the proper placing of the briquette in the clips.

POWER AND EQUIPMENT OF ELECTRIC RAILWAYS.

By H. H. Hunt and C. K. Stearns, Electrical and Mechanical Engineers.

[Read before the Boston Society of Civil Engineers, December 21, 1898.*]

We presume there is no doubt in the mind of any one that the electric car is an ingenious contrivance, and that its utility is demonstrated in our streets by the transportation each day of over 50 per cent. of the entire population; for it is a matter of record that, in the territory contained within a circle whose center is the Government Building in Boston, and whose radius is 15 miles in length, the average person rides nearly 200 times per annum. Doubtless those who live within three miles of the Government Building ride more frequently than 200 times per year, and those who live beyond the three-mile limit ride less frequently; but the reports show that if the contributions were made by all alike in this circular territory it would be necessary for each man, woman and child of us to turn in the considerable sum of $10 every twelve months in order to make up the sum total of the gross receipts of our street railways; a part of one of the most remarkable industries of this century,—remarkable for its wonderfully rapid growth and development, which has resulted in an efficient system for public transportation,—a system whose details have been worked out with much care and whose achievements are admirable as they are satisfactory.

The paper which we have prepared has to do with the modern street railroad and its appurtenances; but, at the risk of "threshing old straw," we will ask your attention to a brief recital of the principal events which mark the progress of the application of electricity to the propulsion of street cars.

While it is not at all certain who first caused a vehicle, of whatever sort, to be propelled by the electric current, we are told that as early as 1834—only a few years after Faraday's discovery of the fundamental principle of electro-magnetic rotation—a veritable electric railroad was constructed by one Thomas Davenport, a humble Vermont blacksmith, whose brain, possessing the proverbial Yankee ingenuity, had conceived a way of propelling a car by means of the electric motor almost as soon as it was known that there *was* an electrical contrivance by which rotation could be produced. Although Davenport devised an electric railroad in every sense of the word, it was only a model, and we may, with reason, safely assume it was a crude one at that. There were no

*Manuscript received January 19, 1899.—Secretary, Ass'n of Eng. Socs.

immediately practical results from Davenport's experiments, which are now remembered simply as interesting events in scientific history.

For the next twenty years or thereabouts experiments were conducted by many ingenious men, both in America and in Europe. But the most important work of this period was accomplished by Dr. Page, of Salem, Mass., who conducted some experiments on a comparatively large scale on the line of the Baltimore and Ohio Railroad, between the city of Washington and a small Maryland town called Bladensburg, just outside the city limits.

Dr. Page hauled a passenger coach over this line by means of an electric motor car; and the report states that he attained a speed of 19 miles per hour. This happened on April 29, 1851, "a day of great historic interest," as one writer puts it.

This experiment, like all others of that period, was a failure from a commercial standpoint; because at that time the only known method of producing the electric current was by means of the primary battery, in principle similar to the batteries which we use to ring our doorbells; and it was a very simple matter to arrive at the conclusion that the elements of the primary battery were altogether too costly a grade of fuel for the transportation of the public.

This first twenty years' experimental work with the primary battery as a source of energy resulted in the production of a miscellaneous lot of electric toys, and it marks the first epoch in the development of the electric railroad. This period would have been of very little more than historic interest had it not been for one thing, which proved later to be of great importance. During this time almost every conceivable method of conducting the battery current to the motor on the car had been utilized, including the third-rail system, the overhead trolley system and the storage battery car system, with the result that when the practical source of electric energy was devised and perfected so that the practical electric railroad was made possible no one was able to patent the application in terms broad enough to prevent others from working on the problem. In other words, the fundamental ideas were common property, and inventors were free to improve and develop these fundamental ideas unhampered by the patent rights of any one syndicate or corporation. This fact undoubtedly accounts in a large measure for the lightning rapidity with which the art of electric traction advanced after it had passed the theoretical stage of its development.

From 1851 to 1873 no important experiments directly con-

nected with the electric railway are reported, but during this time the dynamo, as a source of electric energy, was being improved and perfected, thereby laying the foundation for the solution of the railroad problem by placing before the world a practical method for the production of electrical energy for power purposes on a commercial basis.

The only thing which remained to be accomplished to set the wheels of progress spinning was the discovery of the reversibility of the dynamo, whereby a dynamo-electric machine would revolve as a motor when supplied with electric energy developed by another dynamo-electric machine driven by some prime mover. In the light of our present knowledge it would seem incredible that this simple fact should lie hidden for so many years, especially as it was known that the dynamo-electric machine when supplied with the current from a primary battery would revolve as a motor. It is also a singular fact, and one not particularly creditable to the scientific world, that, in spite of the alleged fact that the reversibility of the dynamo was known in 1850, the real, practical demonstration was not made until 1873, and then simply by accident.

The account of this accidental discovery at the Vienna exposition is well known, and we will not take the time to rehearse it. It will suffice to say that the discovery was of the greatest importance, as it marked the beginning of the period which covers practically all the development of the propulsion of street cars by electricity.

The first six years following 1873 were consumed in desultory experiments which failed, for one reason or another, to amount to much, until Siemens & Halske, in 1879, built a semi-experimental line at the industrial exposition at Berlin. This line was, we believe, the first one which made a business of passenger carrying. It was about 1000 feet long, and could transport twenty passengers at a time at a speed of eight miles per hour. The road was operated on the third-rail system, and is said to have been the "practical starting-point of modern electric traction."

The success of this experiment stimulated invention both in Europe and in this country, which resulted in a commercial street railroad in Europe and several experimental lines in this country, where up to 1883 little or nothing had been done. But about this time Mr. Chas. J. Van Depoele and Mr. Leo Daft began their work, and a little later Messrs. Bentley and Knight appeared, their combined work furnishing some valuable and interesting data. Electric railroading as a business was regarded with distrust, and, while the minds of some of our brightest men were already

engaged on the problems which were rapidly presenting themselves for solution, little or no interest could be aroused among those whose capital was necessary for the substantial advancement of the art.

Next, Mr. Frank J. Sprague entered the field, first applying his efforts to the propulsion of trains by electricity on the New York Elevated Railroad system; and during the next three years he succeeded in putting in a small road at St. Joseph, Mo. This was in 1888, and it marks the end of the period during which the hardest experimental work was carried on, and during which the firm foundations were laid for the remarkable development of the next decade, for at this time the great electric companies entered the field, absorbing all that was good of the experimental work which had been done. The year 1888, which marks the beginning of the "boom" in electric traction in this country, found us with thirteen electric railroads in operation in the United States and Canada. These roads operated ninety-five motor cars over forty-eight miles of track.

The expansion of electric railroading since 1888 is forcibly illustrated by the following extracts from a recent article in the *Boston Evening Transcript:*

"The amount of capital involved in the electric street railways (in the United States alone) is about one and a half billions, and it is increasing rapidly every month. Should the National Government decide to buy all these roads it would take all the $525,000,000 of gold, the $120,000,000 of silver, the $400,000,000 of certificates, the $225,000,000 of national bank notes and $250,-000,000 of United States Treasury notes in circulation to pay for the purchase. The total population of Greater New York, Chicago, Philadelphia and Boston is not greater than the number of passengers carried by the electric cars of the nation every business day. A conservative estimate places the amount of passengers carried in a year by the electric cars at 2,660,000,000, not including the passengers transferred from one line to another. This means two rides each year for every human being on earth. The steam roads of the United States carry only 535,000,000 passengers annually over 182,000 miles of track. . . . .

"The United States companies operate 15,000 miles of electric street railways, employing over 40,000 cars in their service. . . . The payrolls of the electrical railway companies in the United States contain the names of 200,000 men."

With this historical preface we will take up the subject of the paper, "Power and Equipment of Electric Railways."

Our object is to present to you an outline of the principal problems which arise in the design and construction of electric railways, and to indicate the method of treatment. A system of electric railroad consists naturally of four parts:

1. The power station, with its prime mover and electric generators.
2. The outward distributing system or line.
3. The rolling stock, with its electrical equipment.
4. The track and return circuit.

We will take up and consider briefly each of the above topics.

POWER STATION.

The first problem to be solved in connection with the power station is its location. This is determined where the sum of the costs of power, building and real estate and distribution of power is a minimum. The cost of power depends upon the efficiency of the steam and electrical apparatus, and involves the cost of coal and its transportation and water for condensing purposes. The cost of building and real estate involves cost of land, taxes, cost of erecting building on the property foundations and the cost of the building above foundations. The cost of distribution of power depends upon the cost of the overhead conductors, which vary greatly with the location of the power station.

Inasmuch as the conditions which govern these factors are entirely independent and are governed solely by local conditions, it is apparent that the problem of location of station can only be solved by a careful and intelligent series of investigations. This point is one of great importance, and, unfortunately, one which frequently receives little or no attention. If we were presenting this paper to an assemblage of street railway men we should endeavor to impress upon their minds the necessity of intelligently solving the preliminary problems connected with street railway work, for experience has shown that much of the difficulty which is being encountered and patiently endured on many of our electric railways is due to the lack of care with which the original layout was planned.

The style of building is in a measure governed by the taste of the owner and the amount of money to be spent. Modern stations are almost universally of brick, of simple though substantial construction, with roof supported by iron trusses and suitable provision for extension of plant with the least disarrangement of existing apparatus. As in other branches of construction, engineers are continually incorporating new ideas, for convenience in operation and the reduction of operating expenses, in the form of travel-

ing cranes, coal and ash-handling apparatus, mechanical stokers, etc.; but, inasmuch as many of these devices are costly, it is a question to be decided in each special case as to how far such features may be utilized and still prove economical.

No fixed rule for the determination of the number and sizes of the units can be laid down. There are several propositions, however, which we believe are sound, and which should serve as a basis for the solution of this problem:

1. A station should have duplicate units, in order to prevent entire loss of power by the accidental shutting down of a single unit.

2. The units should be so arranged that the average daily power is generated at an economical rate.

3. Suitable provision should be made for all abnormal demands upon the station which can possibly be predicted.

4. Types and sizes of machines should be kept as uniform as possible, in order to preserve the simplicity of the plant and to avoid a multiplicity of repair parts.

Now, with these ideas in view, the logical solution of the problem would seem to be as follows:

First determine the number of cars to be operated by estimating the number of passengers which will be carried per day, also the rates at which passengers must be moved during the hours of maximum traffic, usually nights and mornings, and in some mill localities also at noon. Having determined the nature and extent of the daily work, it is safe to assume that on roads operating five or six cars, the station capacity must be about 50 H. P. per car to provide sufficient power for maximum loads. The average power consumed in the majority of cases is less than one-half this amount, and, as the number of cars operated increases, the allowance of station power per car will naturally approach more nearly to the average consumption per car as the peaks of the load will tend to diminish. The term "peaks of the load" will be explained and illustrated by Figs. 1 and 2, which are plots of the actual power readings in a small power station operating an electric railway. Fig. 1 shows readings taken every fifteen minutes during an entire day, while Fig. 2 shows fifteen second readings during forty minutes. In each case the heavy, straight, horizontal line represents the average power, and the points, showing fluctuations above the average, are what are termed "peaks of the load."

It sometimes happens that peculiar conditions arise which call for even more power than that indicated above; such, for instance, as the simultaneous occurrence on heavy grades of a number of

cars. In such cases, unless the schedules can be so arranged as to avoid this, an extra allowance of power must be provided for the maximum loads.

Having arrived, after a careful consideration of the possibilities, at a clear idea of the nature of the traffic requirements, it will usually be found that during the greater part of the day a normal average load must be carried, and that this normal average load will be exceeded by the average loads of Sundays, holidays, etc., and possibly that it may be very greatly exceeded on certain special occasions, such as ball games, horse races or events which gather together large masses of people.

With this data before us the logical arrangement of station apparatus would seem to be somewhat as follows:

First we should have a unit of sufficient size to take care of the normal average load, and a duplicate of this to allow alternate operation and ample opportunity for frequent inspection and repairs, when necessary, without being obliged to shut down the entire plant or to operate temporarily a larger unit than necessary, with consequent loss in economy. With this duplicate plant somewhat more than double the average load can be handled if necessary, and if the maximum load requires more power a third unit may be installed to provide for this maximum.

In modern stations it is frequently the case that two units are installed, one sufficient for ordinary requirements and the other, say, 50 per cent. larger than the first; the idea being to run the small unit practically all the time, and the larger one in case of emergency or of maximum load. It would seem that, by this plan, one part of the plant must necessarily do much more work than the other, and it would further seem preferable to so arrange the plant that each unit would do its equal portion of the work.

The engine should have an extra heavy fly wheel and be of sufficient size and suitable regulation to hold its speed constant to within 2 per cent. for all variations of load between friction load and 30 per cent. overload.

The question as to whether direct or belted connection should be used is a financial rather than an engineering problem in stations of ordinary size, as the difference in efficiency of direct connection over belted connection in such stations has not been found to be great. The factors which determine the feasibility of the one or the other are: The decrease in floor space, and consequent decrease in cost of building, and the abolition of cost of belting compared with the additional cost of direct-connected machinery over belted.

In almost every case it will be found that the direct-connected plant will exceed the belted in cost, but will, at the same time, be slightly more efficient. A conservative estimate of the difference in efficiency is 5 per cent. in favor of direct connection, so that you have now the necessary elements for determining which form of connection shall be employed.

The best practice of to-day calls for the use of high-pressure steam, with an approved form of water tube boiler. Many plants still use the horizontal return tubular boiler on account of its simplicity and low cost, but in all the largest and best installations in this country the water tube boiler will be found. Time will not permit us to consider the various makes of water tube boilers, whose economy has been found to depend rather upon the efficiency of the fireman than upon the special design of the boilers. The question of the design and arrangement of feed water heaters and economizers must be decided for each special case. In general, only such apparatus as will admit of ease in cleaning and repairs should be selected, and, in the case of heaters, only those having straight tubes should be used when the feed water shows signs of impurity. Copper tubes should also be used. A properly designed system of feed water heaters should save 1 per cent. of coal for each 11° rise in temperature of feed water, and in a well-designed plant the feed water may readily be heated to 200° F.

Economizers show a saving of 10 to 15 per cent. in coal consumption under favorable conditions, and in large plants may frequently be utilized advantageously. In small plants we have not found economizers of advantage, because of the considerable first cost and subsequent cost of operation.

The use of forced or induced draft will often be found advantageous, especially when cheap grades of fuel must be used. Another advantage in the use of fans is the flexibility of such a system, which, especially in railway work, where additions may become necessary, is a very desirable feature. As far as first cost is concerned, the blower system will generally be less than the natural draft with brick stack. It is hardly necessary to add that, in case water can be obtained cheaply, condensers should always be used, giving an increased capacity of the plant of about 20 per cent.

One of the most important features of the steam plant is the piping system, which may be an efficient steam conveyor or a constant source of trouble and annoyance, affecting the safety and economy of the plant, accordingly as the work is properly or improperly done. In general the piping of a steam plant should be so arranged that, in conjunction with its accessories, dry steam will

be delivered to the engines, and all moisture of condensation or otherwise will be carried off by a well-arranged system of drainage. Of course, the system should be laid out to conduct the steam with as little loss in pressure as possible, and a sufficient number of valves incorporated to allow the greatest possible flexibility of the system in case of breakdown of any of the apparatus.

Another point which should receive careful attention is the size of piping. It is preferable to tend toward small rather than large pipe, and to take steam from a receiver placed in the piping system immediately before the cylinder of the engine. This arrangement steadies the flow of steam and prevents vibration of the pipe, a feature which represents loss of energy, liability of leakage and annoyance generally. The loss of heat by radiation is also reduced by the smaller pipe, and the increased friction over that developed in the larger pipe tends to dry the steam. A steam velocity of 100 feet per second has been found to give very satisfactory results on the points above mentioned. Piping should be as short and direct as possible, and extra heavy iron bends are preferable to copper bends.

As to pipe covering, tests at the Massachusetts Institute of Technology, by Professor Norton, at a temperature corresponding to 200 pounds steam pressure, show that, taking the heat radiated from a bare pipe as 100, the heat radiated from covered pipe varies from 15 to 26, according to covering used. Upon the basis of the catalogue list prices he shows that pipe covering will pay for itself in six months' time. Actual bids recently submitted for the pipe covering of an 800 kilowatt plant show that the covering will pay for itself in the saving of coal in about four months' time, so that the item of first cost does not enter materially into the question. As is frequently the case in other matters, the best is the cheapest.

Regarding the electrical apparatus, we will simply call attention to one or two specifications which should be regarded in laying out a plant. The design and capacity of the machines should be sufficient to prevent heating to more than 45° C. above the surrounding atmosphere of any part of the machine except commutator, and 55° at commutator after ten hours' run at full load, one-half hour at 25 per cent. overload and temporary overload at 35 per cent. It is customary and desirable to so build the generators that they will generate 500 volts at no load and 550 volts at full load to help out the drop in voltage, which will presumably occur at the most distant parts of the line at time of maximum load.

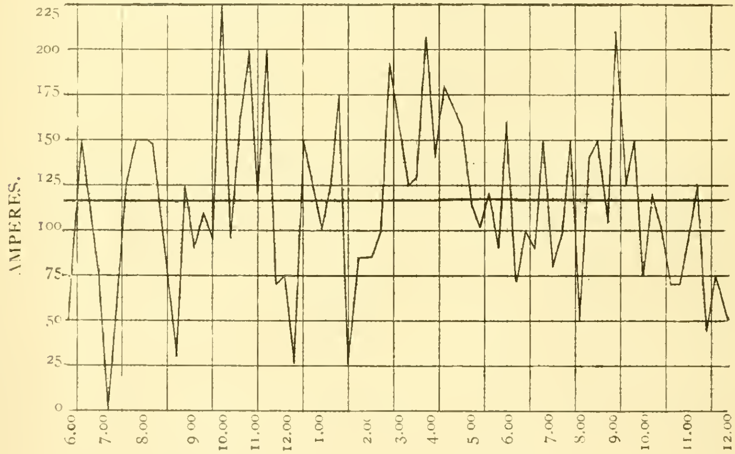
The station should be supplied with an accurate recording watt-meter, for the purpose of measuring the electrical output of

the station, in addition to the regular electrical measuring instruments which are ordinarily supplied with railway switch boards. The watt-meter should be installed and maintained with great care, and calibrated sufficiently often to insure the accuracy of its records. By means of this instrument the net results of the power production at the station are recorded, without which data it is impossible to accurately determine the cost of power.

The character of the load on an electric railway power station is exceedingly fluctuating. Figs. 1 and 2 show the character of these fluctuations. It is evident from the diagrams that the electrical equipment of a railway power station must be much greater in capacity than the average requirements,—*i.e.*, on account of the

DAILY LOAD.

STATION AM-METER READINGS. 15-MINUTE READINGS.



Average Voltage 515. Average Current 116.5.

FIG. 1.

fluctuations, a considerable proportion of the plant must be held in reserve to take care of the peaks of the load. It is plain, therefore, that any device which will store up energy during the time when the load is below the average, and give out the stored energy when the load is above the average, will allow the use of a smaller plant which will be operated under a steady load and at a consequently greater efficiency.

The secondary or storage battery has been used in connection with the ordinary electrical equipment for this purpose, and has served its purpose well. When the plant is originally laid out for the storage battery as an auxiliary a considerable saving in first cost of steam plant can be effected, and consequently a saving in

coal consumption in the manner above described. For plants already built, and not originally designed for the storage battery as an auxiliary, a considerable increase of station capacity may be secured by the addition of a storage battery without the necessity of increasing the steam plant, thereby making it possible to handle an average load equal to the full capacity of the steam plant; the battery taking the peaks of the load. The use of the storage battery for this purpose is one of the later improvements in station practice, and the reports of plants already in operation indicate that the plan is a success.

FLUCTUATIONS.
STATION AM-METER READINGS.

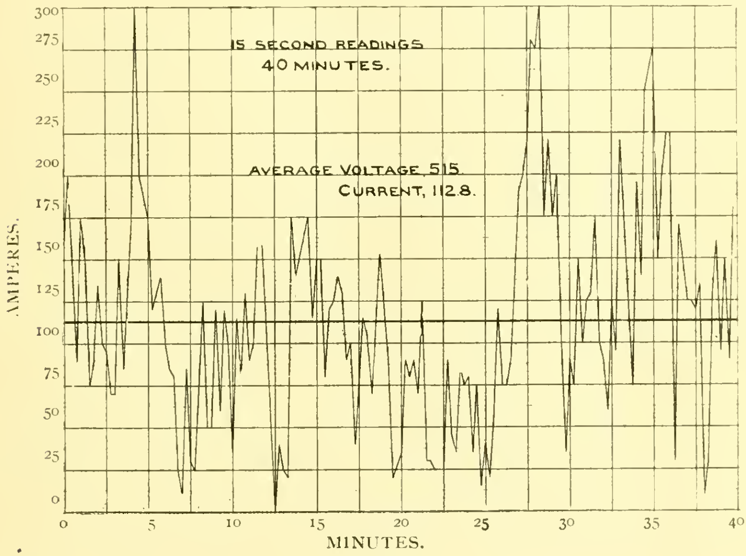


FIG. 2.

OVERHEAD LINE.

The distribution of copper in the overhead distributing system is the most important problem connected with the overhead line. On account of the continual shifting of the load from one part of the line to the other, the ordinary rules for the calculation of copper cannot be applied without modifications and approximations, which judgment alone, aided by experience, can furnish. The requirements of a properly designed system of overhead conductors are that, under all conditions of load, the working pressure of the electric energy shall be maintained within certain limits of safety to the apparatus at every part of the line. A little reflection as to the significance of this statement on lines containing heavy

grades, curves and irregular schedules, etc., will reveal the difficulties of the problem.

In practice it has been found that a road of about ten miles can be satisfactorily operated from one station without an exorbitant outlay in copper. Some roads somewhat longer than ten miles are fed from a single station, but we have frequently found that on such roads, where the attempt is made to transmit power by the ordinary direct-current method at 500 to 550 volts, the amount of copper necessary to do the work is so great that the copper is never erected, and continual trouble is experienced in the form of burned-out motors and slow speed. There are several methods available for operating long lines, such as by increasing the number of power stations and dividing the line into two or more short lines, as the case may require, or the transmission of power at higher voltage than that employed at the car motors.

Anything like a detailed explanation of the various methods of long distance power transmission would require much more space than can be allotted here, as it is a most complex subject. It may be said in general, however, that it is possible to transmit power over about ten miles of road in a very satisfactory manner at 550 volts, and from a single station; and that several ways have been devised whereby this distance may be increased to almost any practical extent; a combination of the two methods above mentioned will afford power transmission for any distance.

The balance of the problems connected with the construction of the overhead line are largely mechanical, and a description of the minutiæ connected with the proper erection of an overhead line would take some time and be little more than a rehearsal of a multitude of details of no special interest to those not directly connected with the construction business. The line should, of course, be suspended in a neat and sufficiently substantial manner to sustain the severe usage to which it will be subjected. One other point of importance is the protection of the line from lightning. Approved forms of lightning arresters should be erected at least every half mile, and these arresters should be carefully installed and maintained. Efficient protection from lightning may save hundreds of dollars damage to the electrical plant, for lightning plays sad havoc with electrical machinery if allowed to enter the station unimpeded.

TRACK AND RETURN CIRCUIT.

The principal mechanical requirements for the track are that it shall be substantially built and carefully maintained. Rough

track, besides being decidedly uncomfortable for the passengers, racks the cars and motors, consumes power and increases the danger from derailment.

The principal electrical problem in connection with the track is the problem of rail bonding,—*i.e.*, the bridging of the rail joints by metallic conductors or bonds so as to provide an uninterrupted path for the return of the current from the cars to the station. No problem connected with the electric railway has occasioned more thought than has rail bonding, and no feature of the electric railroad has proved more troublesome. Defective rail bonds cause all sorts of difficulty. They not only consume power, but frequently interrupt the power entirely. They impose abnormal electrical strains upon the motors, ultimately causing burn-outs and heavy repair bills. Another extremely troublesome outcome from poor rail joints is the electrolysis of water and gas pipes.

Popularly speaking, it is a well-known fact that the electric current always traverses the path of lowest resistance,—the shortest electrical path. A more accurate way of stating this fact would be as follows: If several paths of varying electrical resistance connect two points which are subjected to a difference of electrical pressures or potentials, electric currents (so-called) will flow in each of these paths, and the amount of current in each path will be proportional to the conductivity of the path. This principle is applicable to track circuits, for if there are poor rail joints of great electrical resistance, and there are other continuous masses of metal adjacent to the track whose electrical resistance is less than that of the track, the current will divide itself into parts proportional to the conductivity of the respective paths. Water pipes and gas pipes form very convenient adjacent paths, and practice furnishes many instances where underground pipes have conducted large amounts of electrical energy which should have been conducted in other ways. No injury to the pipe will result from the current in passing to the pipe or as long as it remains on the pipe, but when the current goes from pipe to earth, as it must eventually do in order to reach the power station from whence it came, the trouble occurs. At each point where the current leaves the pipe and goes into the earth corrosive action is set up, which results in the gradual destruction of the iron at this point. This action is called electrolysis, and has proved disastrous to water and gas pipes in some places.

The remedies for this are two: First and best is prevention by proper rail bonds, thereby preventing the greater part of the current from leaving the track. Second, by carefully connecting

the gas and water pipes to the station by means of conductors, thereby preventing the current from passing from the pipe to the earth.

It goes without saying that numberless styles and kinds of rail bonds have been devised. The problem is not an easy one, for the

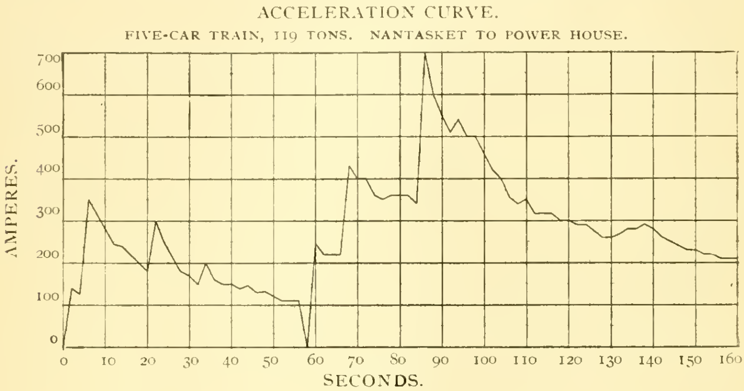


FIG. 3.

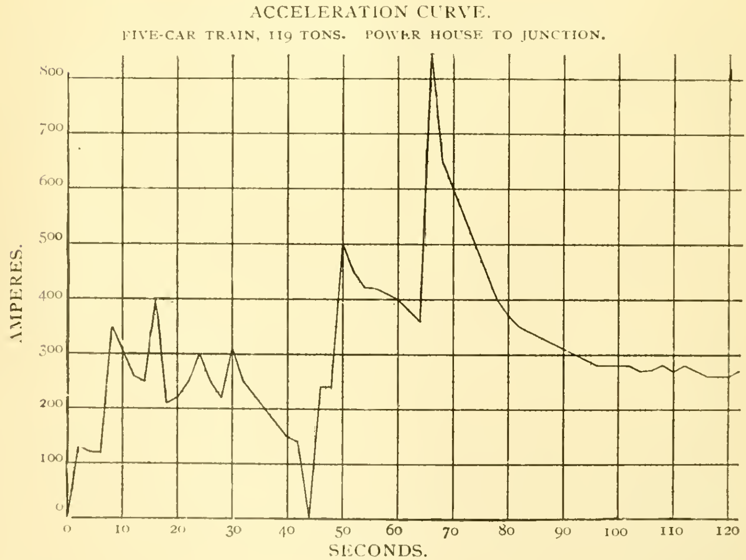


FIG. 4.

bond is in most cases underground, where it is subjected to the action of moisture and the wrenching due to the movement of the joints by the passing cars. It is generally sufficient to bridge each rail joint by two short flexible copper bonds not less than No. 0000 (B. & S.) gauge (.46-inch diameter), the bearing surface between

rail and bond being at least twice the area of the wire. Tinned wire should be used to prevent corrosion, and the rails should be tied together or cross-bonded at every other pair of rail joints. In applying the bonds the holes in the rail should be carefully reamed out and cleaned, and a perfectly tight and solid joint made.

CURVES OF SPEED, TORQUE AND EFFICIENCY.

G. E. 2000-RAILWAY MOTOR.

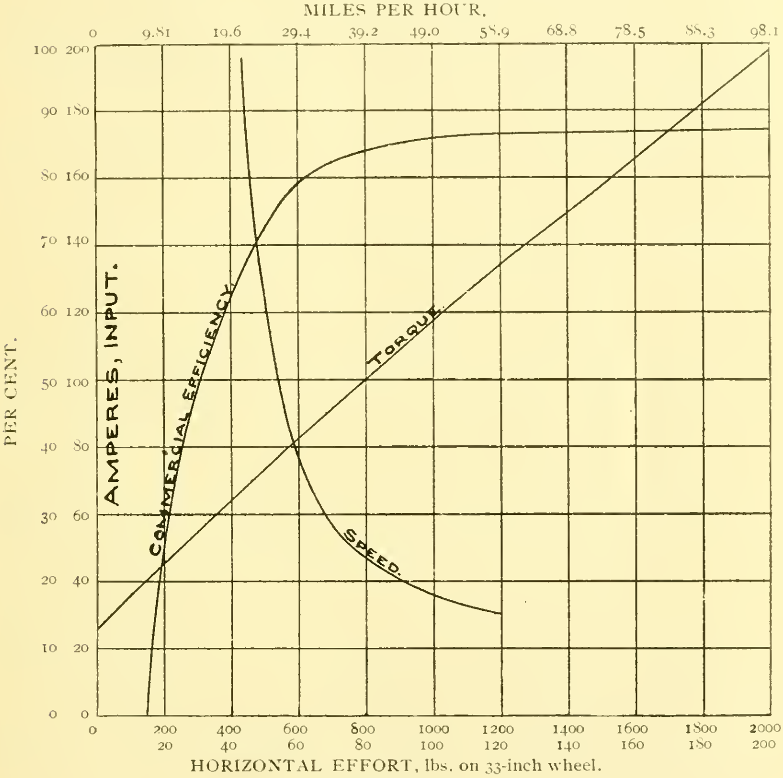


FIG. 5.

ROLLING STOCK.

The only problem which we shall mention in connection with the rolling stock is the determination of the size of motor for a given case. In practice it is generally found that the maximum tractive effort is required during the acceleration of the car, and especially is this the case on elevated railways. Figs. 3 and 4 show the consumption of power during the acceleration of a five-car train, weighing 119 tons, propelled by electricity. Starting from zero, the current increases sharply, then falls to zero, then

rises to maximum and then gradually falls to a constant value. The irregularities in the curve while rising from zero to maximum are largely due to the particular form of car controller which was used on this train. The particular point of interest is the maximum to which the current rises as the acceleration of the car increases, and then the gradual diminution of the current to a constant value as the car continues at its constant speed. While a rapid acceleration is desirable, on account of the efficiency in watt hours per ton mile, it will require a greater maximum tractive effort to obtain this acceleration, and consequently larger motors and also a greater reserve at the station to take care of the increased fluctuations.

It is obviously impossible to take actual measurements of current consumption during acceleration on a road not yet built, but the estimated maximum draw-bar pull may be readily calculated when the weight of the train and the time of acceleration have been settled upon. Having obtained the maximum draw-bar pull, it is necessary to consider it in connection with the so-called torque curves of various motors in order to select the motor adapted to the case in hand. Fig. 5 shows one of these torque curves. Starting with the horizontal effort in pounds, follow the ordinate to its intersection with the torque curve; next follow the horizontal to its intersection with the speed curve; next follow the ordinate from the point of intersection to the scales of miles per hour, which will decide whether this particular motor is adapted for the requirements. The plot also shows the commercial efficiency of the motor at various loads and the current consumption at the various speeds and torques. Motors in use may be estimated at an average running efficiency of 60 per cent. In order, then, to fix the size of the motor it is necessary to know the load to be carried, the speed required, the time in which to develop that speed and the grades to be mounted. The motor should be of sufficient capacity to fulfill these requirements without undue heating.

It is common practice to specify the heating limit as follows: After an hour's run at rated load no part of a railway motor should rise in temperature over 75° C. above the temperature of the surrounding atmosphere.

The foregoing are some of the problems which arise in electric railway practice. If we have succeeded in presenting to you a general idea of their significance and an outline of the methods by which they may be solved, we shall feel that we have, in part, at least, succeeded in our undertaking.

DISCUSSION.

Mr. Alton D. Adams.—It seems timely, in connection with the paper just read, to call more particular attention to the destructive action of electrolysis. The damage in the aggregate from this action is enormous, and in value many times the cost of construction necessary to prevent it.

Uncertainty as to the points at which a water or other pipe system will be attacked in any given case adds to the dangers, and the fact that pipes in some localities suffer but little damage is no guarantee in others. The only security, so long as the single trolley system is used, lies in much greater weight of copper ground returns, so as to lower the electric pressure of the entire ground return system.

DOUBLE-TRACK ELECTRIC RAILWAY FROM BUTTE TO CENTERVILLE, MONTANA.

By Francis W. Blackford, Member of the Montana Society of Engineers.

[Read before the Society, December 10, 1898.*]

The city of Butte and the town of Centerville, one of its suburbs, were connected, in the year 1897, by a cable passenger railway, which did service until about a year ago, when plans were made to substitute therefor electric traction and to make the necessary changes in the alignment and grades.

The cable was run in an almost direct line between the two places. It overcame an elevation of 390 feet between Park street, Butte, and Center street, Centerville, a distance of 0.9 mile, and had grades as steep as 14 per cent.

The plan of the new enterprise was to construct a double-track electric railway, if possible, upon grades not exceeding 5 per cent., and located so as to accommodate the greatest number of people residing in the several settlements lying between the two places.

In pursuance of this plan a number of lines were run in the summer of 1897 by Mr. W. H. Harrison, C. E., under the general direction of the writer, and the possibilities were pretty well understood before the final location was begun. In these preliminary location lines complete circles, of radii to suit the conditions, were used in development, and many interesting engineering features were introduced to overcome the elevation and avoid expensive or objectionable places. It was, however, found to be impracticable to adhere to a grade of 5 per cent., and in the final location grades of 6 and 7½ per cent. were introduced in places, with rates varying from level up to these, as shown by the profile, Fig. 2.

As the location progressed it was found that the right of way was the paramount question, and of greater importance than the physical difficulties to be overcome. While farm and town or city property has a pretty well-established value, easily determined by testimony before a commission, the determination of the value of a piece of undeveloped mining property is a very different and a very difficult matter. The owner of such property can often prove the value of his surface ground, for use in the development of the mine, to be so great in a single instance as to practically kill such an enterprise; and the only thing to do in such cases is to avoid the property, or at least that part of it which is likely to be used for developing the mine.

*Manuscript received December 28, 1898.—Secretary, Ass'n of Eng. Socs.

The company's charter gave power to condemn land for a right of way, but, for the reasons above stated, it was thought best to locate the line upon ground which could be purchased at reasonable prices; and the location was so made, the right of way therefore becoming one of the controlling features of the location.

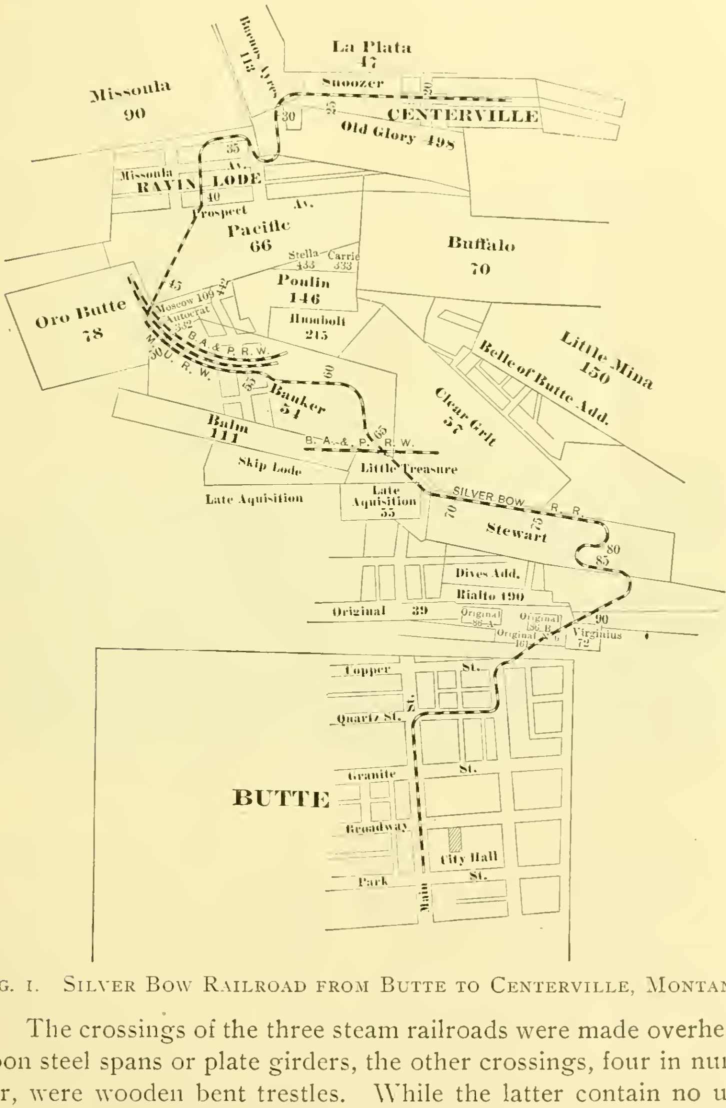


FIG. 1. SILVER BOW RAILROAD FROM BUTTE TO CENTERVILLE, MONTANA.

The crossings of the three steam railroads were made overhead upon steel spans or plate girders, the other crossings, four in number, were wooden bent trestles. While the latter contain no unusual features, the plans were prepared especially for this work. They were planned to carry "Jumbo" cars of 15 tons weight, with a load of 180 persons, or a total weight of 30 tons. The elevation

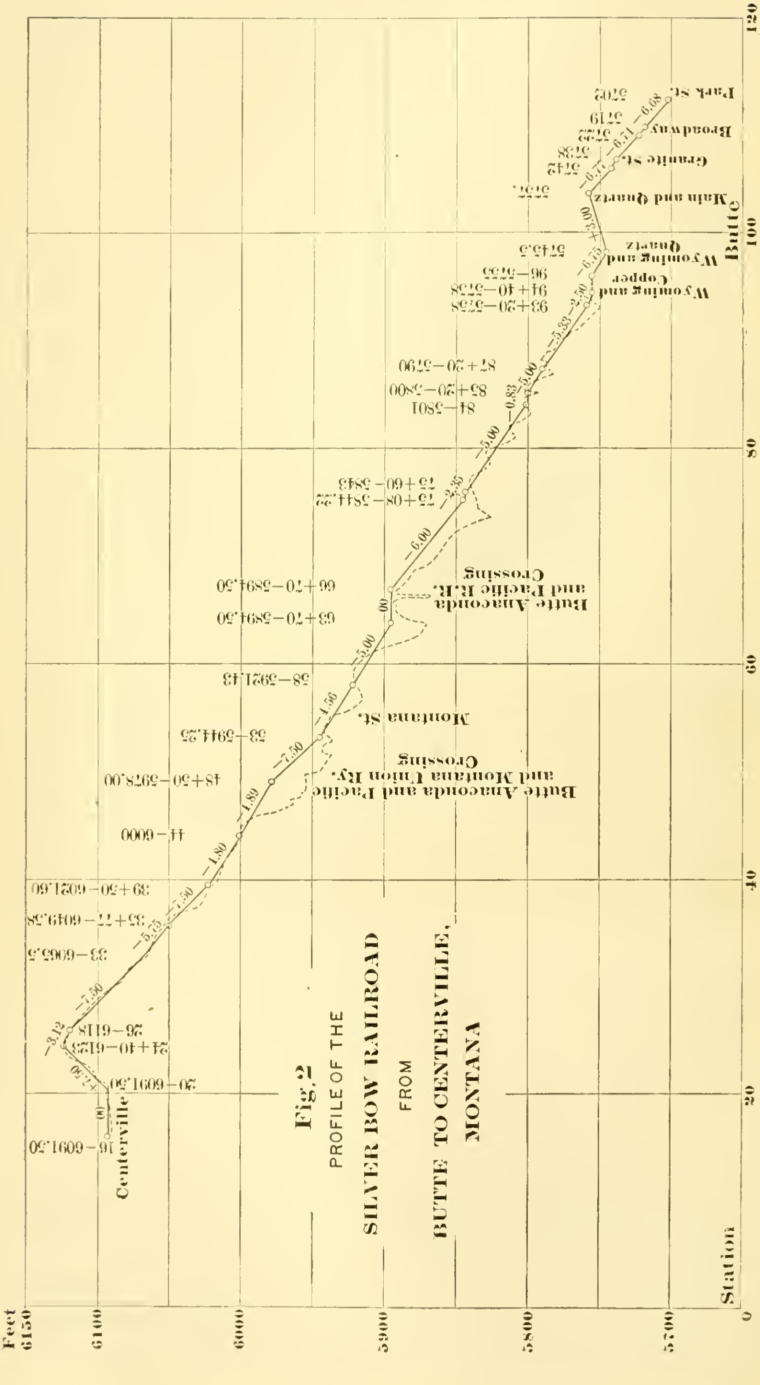


Fig. 2
PROFILE OF THE
SILVER BOW RAILROAD
FROM
BUTTE TO CENTERVILLE,
MONTANA

of the track on curves was computed for a speed of 12 miles per hour, and on the bridges was obtained by means of a false cap.

The curves vary in radius from 64 to 143 feet, with transition curves at the ends increasing 10° every 10 feet upon the lighter curves and 10° every 5 feet upon the heavier ones.

No compensation of grade on curves was made because the power supplied to the cars was ample to enable them to ascend much steeper grades, the objection to the heavy grades being the difficulty in safely descending them. Upon this line, which overcomes an elevation of 416 feet, and has $1\frac{3}{4}$ miles of almost con-

FIG. 3. DEVELOPMENT, WITH 5% GRADE, NEAR STATION 80.

tinuous grade, the safe descent is the special feature of its operation.

Except on the paved streets of Butte, the road is laid throughout with 52-pound second-hand steel rail that had been in use on the Oregon Short Line Railway. The rail was but little worn, and it makes an excellent track.

The rails are bonded with the Atkinson horseshoe bond, N 0000, cross-bonded every 600 feet.

The power is transmitted by the usual overhead wire, supported by cedar poles on each side. The feed wire, however, does not follow the meanderings of the road, but runs straight up the hill and feeds at the crossings and at the end of the line.

The line is equipped with 16-foot single-truck cars, with 30-inch wheels and two 35-horse power General Electric No. 1000 motors on each car.

In addition to the usual chain brake, the cars have the General Electric electric brake, the latter being used as an emergency brake only. They also have the General Electric K-10 controller.

The trip from the corner of Park and Main streets, Butte, to the corner of Center and Main streets, Centerville, a distance of $1\frac{3}{4}$ miles, is made with ease in fifteen minutes, each car making two round trips per hour.

The line has been in successful operation since August 7, 1898, and no accidents or runaways have occurred. In only one instance has the emergency brake been applied.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds

vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

Annual Report of the Chairman of the Board of Managers.

December 31, 1898.

To the Members of the Board of Managers of the Association of Engineering Societies:

Gentlemen:—Your Chairman has the honor to present to the Association through you the annual report of your transactions during the year 1898.

The publication of the Journal, the principal business of the Board, has been managed largely by your efficient Secretary, whose faithful and valuable services should be again acknowledged, and whose lucid report is herewith transmitted. The Journal has appeared with regularity and with reasonable promptness, its general make-up and appearance being in keeping with the excellent character of the papers which have been published during the year. The report of the Secretary shows a gratifying increase in the number of pages of the Journal, although the number of articles

remains but 45, as last year. The attention of the local societies is again called to the desirability of publishing a larger number of papers, thus increasing the value of the JOURNAL as well as extending the advantages of the meetings of the Societies.

The excellent financial condition of the Association, allowing a considerable reduction of annual dues during the year with prospects for further reduction, as exhibited in the detailed report of the Secretary, is a matter for congratulation.

As noted by the Secretary, we have had the pleasure of receiving into our Association three new Societies whose aggregate membership of 204 far more than balances numerically that of the two Societies which have practically gone out of existence. This material growth is also a cause for congratulation.

Aside from the changes in membership and the routine details connected with the publication of the JOURNAL, attention may be called to the following as the more important actions taken by the Board:

A new rule has been adopted regarding advertisements secured for the JOURNAL, the Secretary's remarks concerning which are commended to the careful consideration of the Societies.

The Board voted 9 yeas to 5 nays to allow authors of papers published in the JOURNAL to append to their names, in addition to "Member of ——— Society," such college degrees and scientific society memberships as they may choose, also a statement of their present or past professional position. Experience up to the present time indicates no tendency to abuse the privilege thus extended, and it is expected that no abuse will arise.

The proposition to hold the Secretaries of local Societies responsible for the accuracy of such statements was voted down, as was also the proposition to have the Secretary prepare brief sketches of authors of papers in the JOURNAL.

In order to facilitate the transaction of business the proposition was made to have all ballots close six weeks after the date of mailing blanks to the members of the Board of Managers. Sixteen votes were received, all in the affirmative.

A suggestion from the Engineers' Club of St. Louis that a directory of the members of the Societies in the Association should be prepared and printed in the JOURNAL has been under consideration. Some members of the Board objected to having it printed as part of the JOURNAL, preferring to have it appear as a separate pamphlet to avoid any appearance of padding.

A compromise has been adopted and the list of names and addresses will be included in the proceedings of the current number. If this meets the approval of the Societies an effort will be made to have a complete directory prepared for next year, which shall give not only the names and addresses but also the professional positions occupied by the members. It is hoped that this feature will strengthen the bond of community among the constituent Societies.

As the value of the JOURNAL and of the Association is commensurate with the membership, I desire to raise a question with regard to the desirability of inviting the co-operation of the Clubs of mechanical, electrical and other engineers in several of the larger cities. At present the Association consists of several civil engineering Societies and of others whose names

indicate a wider range of membership. As the articles of Association contain nothing to indicate that the membership was designed to be limited to civil engineers, and as most if not all of the Societies now in the Association include other than civil engineers, I desire to learn the sentiments of the members regarding the desirability of increasing our numbers by encouraging the co-operation of such other engineering Clubs as have professional standing.

In closing I desire to thank the Board for the honor and confidence shown me, to acknowledge the hearty co-operation of the Secretary and to express the hope that during the ensuing year the Association may grow yet stronger and better.

Respectfully submitted,

GEO. D. SHEPARDSON, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 31, 1898.

Prof. George D. Shepardson, Chairman,

University of Minnesota, Minneapolis, Minn.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1898, and of the condition of the Association at the present time.

These data are concisely stated in the following statistical appendices:

A. Statement of receipts and expenditures during 1898.

B. Estimate of assets and liabilities at the close of 1898.

C. Detailed statement of cost of JOURNAL during 1898.

D. Comparison of mailing lists of the JOURNAL, at the close of 1897 and of 1898, respectively.

E. Statement of material in JOURNAL during 1898, by pages.

F. Comparison between operations and conditions during 1897 and 1898.

A comparison of these appendices, and particularly of Appendix F, shows a most gratifying condition of the affairs of the Association, even when compared with the exceptionally favorable year of 1897.

Notwithstanding a further reduction of the annual assessment from \$2.50 to \$2.00 per member, the cash balance at the end of the year shows an increase over that at the end of 1897, and the excess of assets over liabilities shows a still greater increase.

A further reduction in assessments will certainly be in order in 1899.

The assets and liabilities and annual assessments during several recent years have compared as follows:

	Annual Assessment per Member.	Excess of Liabilities over Assets.	Excess of Assets over Liabilities.
1894	\$3.00	\$758.91	
1895	3.66		\$223.93
1896	3.00		1,244.94
1897	2.50		2,562.04
1898	2.00		2,936.71

I still await favorable action by the Societies in the matter of procuring from their members advertisements for the JOURNAL of the Association. In the hope of stimulating such action, the Board of Managers, during 1898,

increased, from 50 to 90 per cent., the discount allowed to Societies for such advertisements, but thus far this measure has borne no fruit.

This is greatly to be regretted, not only on account of the Societies themselves, but also on account of the Association, for its efforts to secure the co-operation of Societies still outstanding would be very greatly strengthened if it could be shown that some, at least, of our Societies secured the advantages of co-operation with the Association without actual increase of cost to themselves.

During 1897 I had the pleasure of chronicling the accession of the Detroit Engineering Society, with 97 members.

During 1898 the Engineers' Club of Western New York, with headquarters at Buffalo, and a roll of 50 members; and the Louisiana Engineering Society, with headquarters at New Orleans, and a roll of 57 members, have joined the Association; and the admission of the Engineers' Club of Cincinnati, with a membership of 97 names, has been practically consummated.

Each new Society admitted to the Association contributes not only to its financial strength but also to the value of the JOURNAL, and thus increases the inducement to outstanding Societies to become members of the Association.

Unfortunately, during the year, the Association of Engineers of Virginia, with a mailing list of 14 names, and the Denver Society of Civil Engineers, with a mailing list of 25 names, have practically become extinct.

The total mailing list of the Societies will have increased from 1252, at the end of 1897, to 1425 at the beginning of 1899.

The average cost per page of publishing the JOURNAL during 1898 was $3.26, as against $3.24 in 1897.

The very trifling increase in the cost per page is far more than accounted for by the large increase in the expense for illustrations during 1898.

The total number of pages in the JOURNAL during 1898 was 1062, as compared with 968 in 1897.

The number of pages published, and the average cost per page during several recent years, have been as follows:

	No. of Pages.	Average Cost per Page.
1894	1290	$4.48
1895	1482	3.99
1896	856	4.59
1897	968	3.24
1898	1062	3.26

It has been thought advisable that the Association should procure the remainder of the stock of the Index of Current Technical Literature, reprinted from the JOURNAL of the Association and published in book form in 1891, covering the years 1884-1891. This stock was accordingly purchased, at a cost of $160, and a number of copies have been bound. Copies of these indexes, amounting to about $100, have been sold during 1898.

JOHN C. TRAUTWINE, JR., *Secretary.*

APPENDIX A.

Statement of Receipts and Expenditures During 1898.

CASH, 1898.

Dr.

To Balance, January 1, 1898		$1,995 53	
" Assessments:			
Boston Society of Civil Engineers	$941 00		
Civil Engineers' Club of Cleveland	343 50		
Engineers' Club of St. Louis	362 00		
Civil Engineers' Society of St. Paul	49 50		
Engineers' Club of Minneapolis	35 75		
Montana Society of Engineers	230 50		
Denver Society of Civil Engineers	6 50		
Association of Engineers of Virginia	24 50		
Detroit Engineering Society	190 50		
Technical Society of the Pacific Coast	270 25		
Engineers' Soc'y of Western New York	100 00		
Louisiana Engineering Society	33 06		
		2,587 06	
" Initiation fees:			
Engineers' Soc'y of Western New York		25 00	
Louisiana Engineering Society		28 50	
" Subscriptions		513 19	
" Sales of Journals		186 36	
" " " Descriptive Index		29 50	
" Advertisements		520 83	
" Sales of Reprints		263 38	
" " " Periodicals		29 85	
" Interest on deposits		23 85	
			$6,203 05

Cr.

By Patterson & White (Printers)	$2,343 89	
" Illustrations	761 52	
" Secretary's salary	600 00	
" Car fares	1 70	
" Mimeographing, etc	17 50	
" Discounts on subscriptions	25 00	
" " " sales	4 15	
" " " advertisements	55 25	
" Messenger service	2 85	
" Stationery	10 50	
" Telegrams	6 82	
" Postage stamps	26 55	
" Express charges	4 66	
" Back numbers bought	8 00	
" Advertising	21 09	
" Binding Journals	3 00	
" Indexes bought	160 00	
" Traveling expenses	33 90	
" Expenses, S. E. Tinkham, Ex-Chairman	13 80	
		4,100 18
" Cash balance, December 31, 1898		$2,102 87

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1898.

AVAILABLE ASSETS.

Cash balance, December 31. 1898		$2,102 87	
Less subscriptions for 1899, paid during 1898		68 50	
			$2,034 37
Amounts receivable from Societies (for assessments, etc.):			
Civil Engineers' Club of Cleveland	$44 25		
Civil Engineers' Society of St. Paul	16 50		
Montana Society of Engineers	162 25		
Association of Engineers of Virginia	3 50		
Technical Society of the Pacific Coast	32 00		
		$258 50	
Subscriptions due:			
For 1898	276 00		
" 1897	105 00		
" 1896 and earlier	108 00		
		489 00	
For reprints		133 60	
" Advertisements		217 33	
" Sales of Journals		14 90	
" " " Index		84 40	
" Copyright fee		1 00	
			1,198 73
			$3,233 10

LIABILITIES.

Patterson & White (Printers):			
For December Journal	$192 30		
" Reprints	34 20		
" Letter heads, etc	1 75		
" Sundries	39 39		
		$267 64	
E. Halfenson		3 50	
Boston Society of Civil Engineers		1 85	
Civil Engineers' Club of St. Louis		9 50	
William Rutter Co		13 90	
			296 39
Excess of assets over liabilities			$2,936 71

APPENDIX C.

Detailed Statement of Cost of Journal During 1898.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Patterson & White. Sum of 1, 2, 3 and 4	Illustrations *	Cost of Manufact'e Sum of 1, 2, 6	Wrappers.	Secy's Salary.	Sundries.†	Total.‡	No. of Pages.§	Cost per Page.
January	$129 17	$124 25	$7 17	$12 06	$272 65	$49 00	$302 42	$4 75	$50 00	$15 25	$391 65	146	$2 68
February	71 43	87 75	5 10	7 48	171 76	70 50	229 68	4 75	50 00	2 34	299 35	82	3 65
March	87 43	87 25	5 62	9 42	189 72	120 09	294 77	4 75	50 00	7 95	372 51	100	3 72
April	99 83	90 75	5 39	10 09	206 06	36 50	227 08	4 75	50 00	18 57	315 88	104	3 03
May	66 90	74 25	6 20	8 27	155 62	129 40	270 55	4 75	50 00	5 40	345 17	82	4 21
June	68 01	70 25	4 65	7 50	150 41	27 94	166 20	4 75	50 00	2 25	235 35	78	3 02
July	38 20	53 25	5 25	6 41	103 11	54 50	145 95	4 75	50 00	3 50	215 86	56	3 85
August	42 43	57 75	5 21	8 62	114 01	144 46	244 64	4 75	50 00	15 00	328 22	62	5 29
September	39 85	59 25	4 50	6 54	110 14	47 99	147 09	4 75	50 00	3 35	216 23	60	3 60
October	51 57	69 75	4 20	7 19	132 71	36 00	157 32	4 75	50 00	7 89	231 35	74	3 12
November	94 20	82 75	4 80	9 41	191 16	13 00	189 95	4 75	50 00	2 30	261 21	114	2 20
December	80 58	90 75	5 60	10 62	187 55	....	171 33	4 75	50 00	7 00	249 30	104	2 40
Totals and averages	$869 60	$948 00	$63 69	$103 61	$1,984 90	$729 38	$2,546 98	$57 00	$600 00	$90 80	$3,462 08	1062	$3 26

*The figures in column 6 include preparation of cuts and lithographic stones, and paper and presswork on insets.

†The figures in column 10 include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal, and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡Sums of amounts in columns 5, 6, 8, 9, and 10

§The figures in column 13 include 4 cover pages in each number and 16 pages in indexes to Vols. XX and XXI.

APPENDIX D.

Comparison of the mailing lists of the JOURNAL, at the close of 1897 and of 1898, respectively:

	1897.	1898.	Increase.	Decrease.
Boston Society of Civil Engineers	470	485	15	..
Engineers' Club of Cleveland	148	177	29	..
Engineers' Club of St. Louis	174	191	17	..
Civil Engineers' Society of St. Paul	36	33	..	3
Engineers' Club of Minneapolis	15	21	6	..
Montana Society of Civil Engineers	97	107	10	..
Technical Society of the Pacific Coast	149	126	..	23
Denver Society of Civil Engineers	26	25	..	1
Association of Engineers of Virginia	40	14	..	26
Detroit Engineering Society	97	91	..	6
Engineers' Society of Western New York	..	43	43	..
Louisiana Engineering Society	..	57	57	..
	1252	1370	177	59
Extra copies to Societies	80	38	..	42
Advertisers	19	19	..	..
Exchanges	102	114	..	..
Subscribers	233	246	13	..
Complimentary copies	14	10	..	4

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Two thousand copies of each number have been printed.

APPENDIX E.

Statement of material in JOURNAL during 1898, by pages.

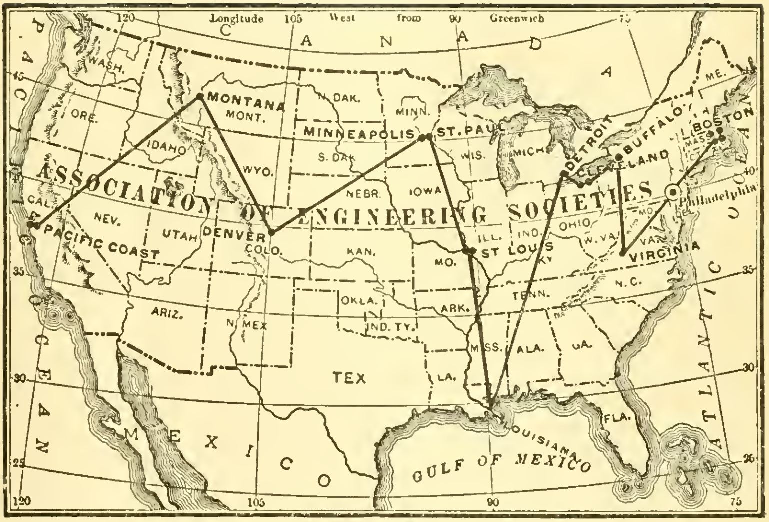
	Papers.	Proceedings.	Chairman's Report.	Advertisements.	Indexes to Vols.	Totals.	Cuts.	Plates and full-page cuts.
January	104	16	10	16		146	37	2
February	56	10		16		82	35	
March	68	16		16		100	28	4
April	74	14		16		104	4	1
May	52	14		16		82	6	14
June	50	4		16	8	78	8	1
July	36	4		16		56	3	1
August	44	2		16		62		13
September	40	4		16		60	3	4
October	52	6		16		74	20	1
November	92	6		16		114	22	1
December	70	8		16	8	102		
Totals	738	104	10	192	16	1060	166	42
Covers, etc						50		
Total						1110		

APPENDIX F.

Comparison between operations and conditions during 1897 and 1898:

	1897.	1898.
Excess of assets over liabilities, December 31	$2,562 04	$2,936 71
Number of Societies in Association, December 31	10	12

Number of names on mailing lists of Societies in Association	1,252	1,367
" " Subscribers	233	246
Annual receipts from subscribers, at $3.00	$699	$738
Number of advertisers	19	19
Receipts from advertisers	$417 50	$520 83
Total pages in JOURNAL	968	1,062
" " of papers	638	738
" cost of JOURNAL	$3,140 43	$3,462 08
Cost per page	$3 24	$3 26
Average number of copies issued monthly	1,796	1,845
Number of small cuts	57	166
" " plates and full-page cuts	45	42
Cost of illustrations	$503 85	$729 38


ASSOCIATION OF ENGINEERING SOCIETIES
Longitude West from Greenwich
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
MEXICO
GULF OF MEXICO
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
CLEVELAND
BOSTON
Philadelphia
VIRGINIA
ST LOUIS
DENVER
PACIFIC COAST
LOUISIANA
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W. VA.
VA.
KY.
N. C.
TENN.
ARK.
OKLA.
IND. TY.
ARIZ.
N. MEX.
TEX
LA.
MISS.
ALA.
GA.
FLA.
ME.
MASS.
MD.
DEL.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXII. FEBRUARY, 1899. No. 2.

HISTORY AND SELECTION OF STREET PAVING IN THE CITY OF NEW ORLEANS.

BY A. C. BELL, MEMBER OF THE LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, December 12, 1898.*]

GEORGE W. CABLE, in an historical sketch of New Orleans, thus describes its site and origin:

The Mississippi River, between the States of Mississippi and Louisiana, flowing at first southward, touches, on its eastern side, at the city of Vicksburg, a line of high, abrupt hills or bluffs, the eastern boundary of its later alluvial basin. The direction of this bluff line is southwesterly; and the river, turned from its southward course by it, flows in this new direction, occasionally impinging upon the abrupt barrier, as at Grand Bluff, Natchez and Fort Adams, and presently turns again with the bluffs, more directly towards the south, striking their base and swinging off from it at Tunica, at Bayou Sara, and finally at Baton Rouge.

Just beyond this point the bluff line swerves rapidly to a due eastward course, and declines gradually until in the Parish of St. Tammany, in Louisiana, some thirty miles from the eastern boundary of the State, it sinks entirely down into a broad tract of wet prairie and sea-marsh; the mainland coast of various inlets from the Gulf of Mexico. It is the general belief that this line of elevated land, now some eighty to ninety miles due north of the Louisiana coast, was the prehistoric shore line of the Gulf.

Close under the Mississippi bluffs, where they make their short turn to the east, the Bayou Manchac, once the Iberville River, and a chain of lakes —Maurepas, Pontchartrain and Borgne—connected by navigable passes and rigolets, formerly (until the obstruction of Bayou Manchac by the military forces of the United States in 1814) united the waters of the Mississippi River with those of Mississippi Sound. Meanwhile the river itself, turning less abruptly and taking a southeasterly course, cuts off between itself and these lakes a portion of its own delta formation.

*Manuscript received January 21, 1899.—Secretary, Ass'n of Eng. Socs.

This fragment of half-made country, comprising something over 1700 square miles of river shore, swamp and marsh lands, was once widely known as Orleans Island.

In outline it is extremely irregular. Its most regular boundary, that of the river bank, is very tortuous, while its width varies, even in its older portions, from fifty-seven miles across the Parishes of Plaquemines and St. Bernard to less than five miles from the river at English turn to the margin of Lake Borgne; another narrow region is seen between the river and Lake Pontchartrain, where these two waters approach to within six miles of each other.

This occurs at a point almost equally distant from the closed entrance of Bayou Manchac, the upper end of Orleans Island, and its lower end at the mouth of the Mississippi. In other words, it is one hundred and seven miles above the point where the waters of the river finally meet the seat at the outer end of Eads' jetties, in latitude 29° 56′ 59″ and longitude 90° 04′ 07″ west from Greenwich; distant 1242 miles by river or 700 by rail from St. Louis; 1760 by sea or 1377 by rail from New York; 4800 from Liverpool, and 4800 from Havre. On this spot, in February of the year 1718, was founded the city of New Orleans.

This site, which Bienville had chosen a year before, offered, to a superficial glance, but feeble attractions. The land, highest at the river's edge, where it was but 10 feet above sea level, sank back within the course of a mile to a minimum of a few inches. It was covered, for the most part, with a noisome and almost impenetrable cypress swamp, and was visibly subject to frequent if not annual overflow. One hundred miles and more lay between the spot and the mouth of a river whose current, in the time of its floods, it was maintained no vessel could overcome.

But the sagacity and Canadian pioneer craft of Bienville had seen its advantages. The Bayous St. John and Sauvage, navigable by small seagoing vessels to within a mile of the Mississippi's bank, led by a short course to the open waters of the lakes, and thus to the streams emptying into those lakes on their farther side, to the countries pierced by these streams, and eastward through the same lakes to Mississippi Sound and the Gulf of Mexico. On the opposite side of the Mississippi another easy avenue to and from the sea was presented by Bayou Barataria, and the network of streams and bays of which it forms a part. By the same waters the wide countries of the Atchafalaya, the Attakapas and the Opelousas were also made accessible, while northward the Mississippi and its great valley stretched beyond known limits.

Here, therefore, M. de Bienville decided to establish the port which later became his capital, and placed a detachment of twenty-five convicts and as many carpenters, who, with some voyagers from the Illinois, made clearing and erected a few scattered huts along the bank of the river.

In 1721 warehouses had already been erected, and Bienville, in certain governmental regulations, reserved the right to make his residence in the new city. During the year 1722 the seat of Government was transferred from Biloxi to New Orleans, and at that time the town contained 100 houses and 300 inhabitants.

The cession of Lousiana (of which New Orleans was the capital) by the French to the United States, in 1803, placed this city under American control. The population at this time was 10,000.

The exports exceeded in value $2,000,000, and the imports reached the sum of $2,500,000. The houses numbered about four thousand; the streets were straight, fairly spacious, but unpaved, ill-drained and filthy, poorly lighted and often impassable to vehicles by reason of the mire. The unpaved sidewalks were commonly bordered by wooden ways of four or five feet in width, while a few in the heart of the town had narrow walks of brick.

The year 1820 found the city with a population of 41,000. The inhabitants were realizing the necessities for improvements. The ancient parallelogram of ditch and palisades that had so long marked the city's ultimate bounds had disappeared in 1808, and the town was spreading far beyond it on every side. Improvements were being rapidly made in the narrow streets of the old town, as well as in the broader ones of the suburbs; and halls, churches and schools, stores, warehouses, banks, hotels and theaters went up in rapid succession.

These improvements and the growth of the city called for the paving of the streets, which, up to the present time, were unpaved, with the exception of Gravier street, between Tchoupitoulas and Magazine streets, which had been paved in 1817 with cobblestones; this material being brought by sailing vessels as ballast.

This square of paved street having proved such an improvement over the unpaved ones, and demonstrated that the streets could be paved, notwithstanding the yielding nature of the soil, we find that in 1820 the wooden sidewalks and curbs on the main thoroughfares gave place to others of brick and stone; and in 1822 a general paving of the principal commercial streets, both in the old and new town, was begun.

The experience with paved streets having proved satisfactory, and demonstrated to the public that streets could be paved on our soft soil, the City Council, September 22, 1827, passed an ordinance for the paving of streets and the making of sidewalks in the city of New Orleans and its incorporated suburbs.

The ordinance being too lengthy to be embodied in this paper, I will give a synopsis of the articles relating to paving.

Article I provided for a tax on all immovable property within the incorporated limits, to be paid at once by all owners fronting on streets and sidewalks already paved, by other owners, three months after the paving was completed.

Article II provided that the City Surveyor should assess this tax according to actual cost, two-thirds of which to be paid by owners and one-third by the corporation.

Three methods of settling for this paving were given the property owners.

First. The City Surveyor was instructed to add 8 per cent. per annum for twenty years on actual cost of paving, one-twentieth of the total to be paid annually for twenty years.

Second. Option was given to the owners to pay the actual cost in cash.

Third. The actual cost in notes, payable in six, twelve, eighteen and twenty-four months, with interest at 8 per cent.

Article III explains the division of cost of pavement of streets and sidewalks to be never more than one-third to the city when property on both sides of street is private. In cases of improvements in front of public buildings or city property, then the city to pay two-thirds, or the total of the cost, as the case may be.

Article V states that all owners who have already paved their sidewalks satisfactorily shall be reimbursed in proportion to present ordinance.

Article VI. On the petition of two-thirds of owners the corporation must proceed to pave according to Articles I and II of present ordinance.

Article VII. The city pays the total cost of all intersections.

Article VIII lays out the progress of the work for paving sidewalks, until full completion of all sidewalks within the corporate limits.

Article IX provides that all moneys received from owners in the original town shall be disbursed within the original town; all moneys received from owners in the suburbs shall be disbursed within said suburbs, in accordance with an ordinance of September 8, 1827, authorizing the borrowing of $50,000 for paving improvements within the original city only.

Article XI. Paving of streets and building of banquettes shall be adjudicated to the lowest bidder by the Mayor, all materials being furnished by the corporation.

Article XII. The City Treasurer shall collect the taxes, notes, etc., provided for this ordinance; he shall keep a separate account and see that none of these funds be employed for any other purposes than paving of streets, construction of sidewalks and purchase of material for same.

The material used in street paving under this ordinance appears to have been shell, cobblestone, square block and flat stone, which, from the description, must have been curbstone laid flat on the street surface. The first time the use of planking for street paving is mentioned is in 1837, when an ordinance was

passed for paving certain streets with flatboat gunnels. This method of covering the mud streets must have been used at an earlier date, as the flatboats used for floating down the river the products from the country above furnished the material at a very reasonable cost, these boats being broken up at the end of their voyage.

In 1838 an effort must have been made to determine the relative merits of street paving materials, as an ordinance passed February 27, 1838, provides "that St. Charles street, from Poydras street to Girod street, be paved in the following manner: One-third in stone blocks, one-third in curbstone laid flat, one-third in hexagonal blocks of pine wood." The stone and wood blocks evidently proved satisfactory, as their use was continued as a paving material.

During the years 1827 to 1880, inclusive, the records show that a large number of streets in the area bounded by the river, Felicity road, Basin and Esplanade streets, were paved, and a few of the main streets parallel to the river were paved as far as the upper limits of Lafayette, or to Toledano street; and some of the streets leading from the river were paved as far as Metairie road. Only two roads were paved to Lake Pontchartrain, one along the west bank of the New Basin and the other along the east bank of the Bayou St. John.

The character of pavements laid during this period was planking laid on stringers, shells, cobblestones, flat stone, square blocks and wooden blocks. Shells were used on the roads in the suburbs, and the other material was used in the urban part of the city where traffic was heavy.

The following tabulated statement shows the length and character of the pavements laid up to the year 1880:

Character of paving material.	Miles.
Plank road	4.88
Shell	23.54
Cobblestone	32.94
Stone blocks	22.06
Broken stone	8.87
Nicholson (wood block)	1.66
Total	93.95

The estimated unit cost of each is as follows:

Plank road, per 1000 feet, board measure	$18.50
Shells, per running foot of 20 feet width	2.25
Cobblestone, per square yard	2.25
Stone blocks, per square yard	4.75
Broken stone, per running foot of 20 feet width	2.25
Nicholson, per square yard	3.40

The total length of the streets of New Orleans was 566.29 miles, of which 472.34 miles were unpaved, or about 83 per cent. The population at this time was 216,000, and the value of exports amounted to $90,238,503 and the imports to $10,611,353. Asphalt, or a paving material which at that time was called asphalt, was laid in 1880 on Gravier street, between Front and Delta streets. The life of this pavement was short, as it soon went to pieces under the heavy traffic to which it was subjected.

The Cotton Centennial, held in 1885, at what is now Audubon Park, forced upon the city the necessity of paving St. Charles avenue, one of the principal avenues of the city, and the only means of access for vehicles to the exposition grounds. The material selected was asphalt, and the close of the year 1885 found St. Charles avenue paved with this material on both roadways, from Delord, now Howard avenue, to Lousiana avenue, and the river roadway to Carrollton. This material, owing to its durability, smooth surface and excellent sanitary qualities, at once found favor with the public, and has so continued to this day.

The year 1889 marks the introduction of concrete gravel pavements, and during the years 1889 to 1896 a large number of streets in the Fourth, Sixth and Seventh districts were paved with this material. These districts had already commenced to show improvement, but with the advent of this pavement improvement was rapid, due in large measure, I think, to the betterment of the streets. The selection of this material and the paving with it of so many streets proved unfortunate, to say the least. The material was concrete in name only, and the result is that to-day we have a large mileage of street pavement, for which large sums have been expended, which are but slightly better than the old dirt streets which they replaced. However strongly we may condemn gravel as a paving material, this should be placed to its credit: that while it remained in good surface it served as an illustration of the benefits to be derived from well-paved streets.

Vitrified brick was first laid in this city in 1894, being laid in the First, Second, Third, Fourth, Fifth and Sixth districts.

In 1895 chert pavement was introduced; but a small amount has been laid, two streets in the First and two in the Sixth district having been paved with it.

Street paving is carried on by special assessment levied on the abutting property, three-quarters of the cost in the case of ordinary streets, and two-thirds in the case of neutral-ground streets; the city paying the other one-quarter or one-third and the whole cost of intersections.

The Council can, in the matter of repaving of streets, order the work done at the cost of the city. The legislation is by petition, signatures of property owners to the amount of one-quarter of the total front footage being required. Protest requires the signatures of a majority of property owners by foot frontage. By a two-thirds vote, the Council can require the paving of a street, the cost to city and property owner being prorated as indicated above, according to the character of the street, whether ordinary or neutral ground streets.

As the construction of the pavements that have been mentioned in this historical sketch may not be familiar, I will endeavor to illustrate their construction.

Plank road. This pavement (if it can be so called) was constructed by bedding in the sub-grade stringers 4 x 8 inches or 4 x 12 inches, spaced 4 feet apart, and laid longitudinally of the street; on these stringers were placed transversely of the street planking 2 x 12 inches or 3 x 12 inches, securely spiked to the stringers; the material used was either yellow pine or cypress.

Cobblestone pavement. This pavement was constructed by thoroughly compacting the sub-grade after it had been brought to the proper surface, and then spreading on this six inches of river sand, in which the cobblestones were bedded and thoroughly rammed.

Square block. This method of paving consists of the preparation of the sub-grade to a uniform compact surface by excavating and thorough tamping or rolling; on this sub-grade is placed four inches of river sand, in which the stone blocks are bedded and rammed into position. The blocks are of granite, about 10 x 14 x 8 inches in depth; the joints between these blocks are from three-quarters to one inch in breadth, and are filled with fine gravel.

Belgian block pavement consists of the preparation of sub-grade as previously described; on this sub-grade is laid six inches of concrete and on this two inches of sharp sand, in which the blocks are bedded and rolled with a heavy roller, or rammed; the joints are partly filled with fine gravel and then filled with paving pitch. The blocks are of granite, 4 x 10 inches and 5 inches in depth.

Vitrified brick. The preparation of the sub-grade and laying of concrete and sharp sand, and bedding the brick in same, is as described for Belgian block pavement; the joints are filled with either paving pitch or cement grout.

Asphalt pavement. Preparation of sub-grade and laying of

concrete foundation same as for Belgian block and vitrified brick; on the concrete foundation is laid a binder 1½ inches thick, and on this the wearing surface, 2 inches thick, of asphalt is laid.

Wood block pavement consisted of a thoroughly compacted sub-grade on which was laid 1 x 12-inch tarred planking. The wood blocks of heart pine, after being dipped in hot tar, were then placed on this planking and the joints filled with fine gravel and pitch.

Shell roads consist of a thoroughly compacted sub-grade on which is laid 6 inches of oyster shells, which are rolled with a heavy roller; on this is then spread 6 inches of lake shells, which are rolled with a heavy roller to a uniform surface.

Gravel and chert are paving materials which are treated in the same manner in the construction of a roadway, and the same description will answer for both. The sub-grade is excavated to proper depth and compacted by rolling or tamping; on this sub-grade is laid 1 x 12-inch cypress planking, and on this is laid the first layer of paving material 6 inches thick, which is sprinkled and rolled; the pavement is completed by the addition of two more layers, each 3 inches in thickness, sprinkled and rolled, the last layer being compacted by successive sprinkling and rolling until a compact uniform surface is obtained. The following tabulated statement shows the character and mileage of the street pavements in the city of New Orleans to August, 1898:

Character of paving material.	Miles.
Plank roads	40.64
Cobblestone	40.49
Square block	26.14
Belgian block	2.32
Vitrified brick	5.83
Asphalt	11.98
Wood block	0.06
Shell roads	21.83
Gravel roads	42.55
Chert roads	2.78
Total	194.62

The estimated unit cost of each is as follows:

Plank road, per square yard	$0.56
Cobblestone, per square yard	2.00
Square block, per square yard	5.00
Belgian block, per square yard	4.25
Vitrified brick, per square yard	2.50
Asphalt, per square yard	3.10
Wood block, per square yard	3.40
Shell roads, per square yard	1.00
Gravel roads, per square yard	1.50
Chert roads, per square yard	1.75

At the present time the total length of the streets open to use is 700 miles, of which 505.38 are unpaved, or about 72 per cent. The population at the present time is 275,000, and the area in which the streets are opened is 20 square miles; the area protected from overflow by levees is 39 square miles, and the total area in the incorporated limits is 196¼ square miles.

It is interesting to note the gradual expansion of the city from a small hamlet containing one hundred houses to its present size. In 1728, ten years after being established by Bienville, it contained an area of 3-16 square miles; in 1798 the area was 5-16 square miles, and in 1815 the area was 1¾ square miles; in 1841 the area was 3¼ square miles; in 1871 the area was 15⅝ square miles.

A history of the street paving of a city naturally brings up for discussion, "What is the most suitable pavement for the variety of conditions that are found in the streets of a large city?"

As illustrated in the historical part of this paper, in the early times availability generally determined the kind to be used, but as our cities increase in size and importance, and the varying conditions governing the use of the streets become more complex, the question of a suitable pavement for the different conditions becomes a vital one, and has received and is now receiving serious consideration. This problem is not easy of solution, as a pavement that may suit some conditions will not suit all.

Mr. Geo. W. Tillson, member of the American Society of Civil Engineers (who has given the subject of street paving much study), read before the Washington convention of the American Society of Municipal Improvements, October, 1898, a paper, entitled "A Study of Paving Materials," which contains so much valuable information on this subject that I feel justified in quoting from same:

A perfect pavement should be cheap, durable, easily cleaned, present little resistance to traffic, not slippery, cheaply maintained, favorable to travel and sanitary.

The question of first cost is very important. As with individuals so it is with corporations; what is not economical in the end must often be given up and an inferior article adopted, because the available funds will not permit the required outlay. If the best cannot be used the one nearest to it must be taken, provided it comes within the appropriation. An advocate of a new paving material is almost invariably met with the question, What will it cost? If the price be extreme he will have a hard task to introduce it, no matter how great his other attractions may be.

Durability is probably the most important quality of any material. Ultimate cost depends as much upon this as upon first cost. No matter how cheaply a pavement may be laid, or how pleasing it may be, if it require constant and frequent renewal its real value is greatly diminished. This is especially true in large cities, as the delay and inconvenience to

business on a crowded street may often amount to more to abutting tenants in dollars and cents than the actual cost of the pavement. In a country, too, like America, where the tendency is to build and then allow repairs to take care of themselves, durability is most important.

The growing demand for clean streets in our cities has brought into prominence any pavement that can be easily cleaned. What this amounts to in money can be appreciated by a statement made in December, 1896, by Colonel Geo. E. Waring, Jr., at that time Street Cleaning Commissioner of New York City.

At a meeting of the American Society of Civil Engineers, he said that if all the streets of New York were paved with asphalt, where the grades would permit, and the street car tracks constructed with grooved rails, the cost of sweeping the entire city would be reduced from $1,200,000 per annum to $700,000. That is, there would be a saving annually of $500,000, which, capitalized at four per cent., would amount to $12,500,000 in a city that at that time had a pavement mileage of 431 miles, of which ninety-four were already paved with asphalt.

Resistance to traffic is an important item. In fact, one of the chief provinces of a pavement is to reduce this, and consequently a pavement that can bring this to a minimum is of particular value. A mechanical device that would reduce the friction of a machine fifty or even twenty-five per cent. would be of incalculable benefit, yet a good pavement on a street accomplishes this. It makes one horse do the work formerly performed by two.

The slipperiness of a pavement depends primarily upon its material, but a great deal depends upon its condition. The former will be considered here.

The efficiency of a draft horse must vary with his foothold. If it be good he will be able to use his entire strength to draw his load, while if he be in constant danger of slipping and falling he can accomplish very little.

The relative slipperiness of the different materials often has been discussed. It varies greatly with its condition. For instance, asphalt is more slippery when it is dirty and wet; granite when it is clean and dry. Extended observations were taken in London by William Haywood, engineer of the Commissioner Sewers, in 1873, to determine the number of accidents occurring on different pavements. From his results he deduced that a horse would travel 132 miles on granite, 191 miles on asphalt and 330 miles on wood without having an accident of any kind.

In 1885, Captain, now General, F. V. Greene had a series of observations made in ten of the principal cities of this country for the same purpose. From these he decided that in the United States a horse would travel on wood 272 miles, on granite 413 miles and on asphalt 583 miles without an accident. In both of these cases the falls were divided into those upon the knees, the haunches and complete falls. Falls upon the knees on a rough pavement should not wholly be charged to slipperiness, as a great many must have been caused by stumbling. Captain Greene found that of a total of eighty-four falls, sixty-eight were upon the knees; assuming that one half of the latter were stumbles only, the deduction would be that a horse would travel 698 miles on granite without an accident due to slipperiness. These results of course are general.

Maintenance is closely allied to first cost unless it be known and considered in the adoption of a material, a choi e cannot be made intelligently. What seems to be sound selection will often be ruled out by the cost of repairs. Any material will require constant attention, but that one which needs the least and permits that to be done with the least inconvenience to the public is of most value.

By favorable to travel is meant the ease and comfort that is enjoyed in driving over a smooth pavement, and the decrease in the wear and tear of vehicles and horses. No attempt ever has been made to measure this in actual money, but it is known to be great. It is a pleasure to drive over some pavements, and actual pain to drive upon others. As our streets are for enjoyment as well as use, this property must be considered. The large number of bicycles constantly on our highways makes this especially important.

Another function of a pavement is to preserve health. In large cities it is impossible to prevent decaying matter from being deposited in our streets. If a pavement be of such a character that any of this collects in joints, so that it is not removed by the street cleaners, it cannot but be very deleterious to the general health.

Consequently a pavement that is impervious to water, has a smooth surface and is not itself composed of organic matter will be sanitary.

Noise, too, must be considered. A noisy pavement prevents sleep, rasps on the nerves of the sick and prevents conversation on the street. This question of noise is of such importance that in Greater New York estimates have recently been made for repaving around all schoolhouses in the city with a smooth and comparatively noiseless material.

Mr. Tillson in his paper assigns an arbitrary value to the different qualities required of pavements as previously enumerated, and by deduction determines the pavement suitable for the conditions found on any street. Using the qualities outlined in Mr. Tillson's paper, I will endeavor to determine the most suitable pavement for the various conditions imposed by our business, residence and suburban streets. Eliminating from the discussion planking and cobblestone as being obsolete, the discussion then assumes this form: The use of square block or Belgian block for streets in the business section subjected to heavy traffic; asphalt and brick for streets in the business section subject to light traffic, and also for residence streets; gravel, shells and chert for suburban streets.

Square block is expensive in first cost of construction; if kept in proper surface and repair, expensive to maintain, and therefore not durable; owing to the large joints and the lack of cohesion of the filling, it is a pavement difficult to keep clean, and therefore unsanitary, as the joints retain any deleterious material that may be swept into them. The surface not being uniform, it offers great resistance to traffic. The large area of surface of the blocks, which soon become smooth and polished under traffic, renders this class

of pavement very slippery. It is therefore evident that square block possesses none of the qualities of a good paving material, and should be rejected.

Belgian block, owing to its method of construction, has all the qualities of a durable pavement; easy of maintenance and offering but little impediment to cleaning, and therefore in a measure sanitary. Owing to the small size of the blocks and the number of joints, it offers a better foothold to horses, and is therefore nearly free of slipperiness. The objections to be urged against it are that it offers considerable resistance to traffic and is very noisy, but these objections are minor considerations in streets of the business section devoted to heavy traffic. Belgian block should therefore be selected for this service.

Asphalt and vitrified brick. The distinction between these two paving materials is so slight that it is difficult to make a selection. One is equally as durable as the other; cost of maintenance is about the same. Brick is not as slippery as asphalt, but asphalt is more easily cleaned, offers less resistance to traffic and is more sanitary than brick. With our present prices the cost of asphalt is less than brick; but, even were the case reversed, asphalt should be selected for our retail business or residence streets.

Gravel, chert and shell. As these materials are only suitable for suburban streets, the qualities necessary to be considered are durability, resistance to traffic and maintenance. Our experience with gravel has been so unsatisfactory it should certainly be rejected. Experience with chert has shown it to be durable and easily maintained under light traffic, and offers but slight resistance to traffic. Shells are not durable, pulverizing under traffic, and the dust is blown and washed away. This loss of the material increases the cost of maintenance. The resistance to traffic is great, owing to the size and shape of the shell and the lack of cohesion of the material until it has become thoroughly pulverized. The first cost of chert is greater than that of shell, but, owing to its slight cost for maintenance and light resistance to traffic, the choice should rest with chert for suburban streets with light traffic.

Having determined on the character of the paving material to suit the conditions found on the different classes of streets, the next problem that confronts the municipal engineer is to ascertain that he gets the material specified, and in the proportion asked for. This can only be accomplished by rigid inspection. The lower grades of pavements can be inspected by observation on the work, but the higher grades, such as Belgian blocks, asphalt and brick, and the concrete foundations of same, can only be determined by

physical and chemical tests. A testing laboratory is therefore a very essential part of the equipment of any municipal department having charge of the construction of public works.

Asphalt, up to a few years ago, was laid by one or two companies, who obtained their material from the same source; and, as it was of the same quality, similar methods of manipulation were followed, and the resulting pavements were satisfactory.

At the present time new sources of supply have been developed, and new companies are entering the field. The engineer's knowledge of this material and its manipulation must be equal to that of the contractor or his experts. This technical knowledge is absolutely necessary to properly guard the interests of the municipality, both in the preparation of the specifications governing the work and the determination of the character of the material and the ability of the contractor to properly manipulate the material and furnish a satisfactory pavement.

It may be urged that pavements are laid under a guarantee, but why should a city be content with a pavement that may last five years if, by proper inspection, the life may be increased to eight or even to ten years; and if, with the knowledge thus obtained, the city may be enabled to make her own repairs if she so desires?

This acquisition of knowledge of the material and its manipulation broadens the field of competition, and, as has been truly said by an expert on this subject, "there is no more reason why a few people should control, through their superior knowledge, the laying of asphalt from Trinidad and other sources of supply than that a similar number should control all the rubber that comes from Para for the manufacture of bicycle tires."

Washington and Brooklyn are both equipped with testing laboratories, and the improvement in their street work and their increased knowledge of paving materials attest the value of the system. The Washington authorities have established standards of material for contractors, and their dictum is never questioned. They assume to know as much as or more than the contractors, and the results have proved the assumptions to have been correct. They did not hesitate to condemn an entire cargo of asphalt. They won the respect and confidence of the contractors by doing and being right.

THE UNITED STATES NAVY.

Personnel Reorganization its Greatest Need.

By William B. Cowles, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 24, 1899.*]

Throughout that great area of our country populated since 1812 and lying between the Blue Ridge and the Sierra Nevada the United States Navy has been heretofore almost an unknown quantity. Americans within this area had hardly given it a thought, except as a matter of dry statistics of State, generally overlooked, unacknowledged and entirely foreign to their sphere of life.

It was very different with regard to the army. With the exception of the War of 1812 and the small operations against the Barbary States, our wars had been entirely within our borders or on adjoining land, and were confined to army operations, the fleet being an adjunct. Ex-officers and men of the army had absorbed a large and deserved share of public attention and emolument; military posts were scattered throughout our domain, and hardly a family North or South was without its military record or tradition. In fact, we knew and were part and parcel of the army, and had practically forgotten the importance of the navy, because the latter did not enter our inland life, and its bearing on international affairs and trade had not been forced upon our attention. The time had not come for us to "take our place among nations"; we were engaged in the development of our great inland domain and in domestic commerce; railroads and the changes they brought absorbed our thought; the sea was to us but a vague geographical fact, and not a vital element of our prosperity. The American clipper, once known wherever tides rolled, had been chased from beneath the stars and stripes by the "Alabama" and the "Shenandoah," and bad laws, together with the lack of good ones, had prevented its return. International communication, imports and the export of our immense food products were almost entirely in the hands of foreigners, and we were willing they should remain there; our manufacturers rather sneered at foreign markets; they seemed satisfied with supplying the home demand; and lastly, our laws did not favor or encourage the deep sea shipowner, though they made a point of searching out and nursing almost every other possible industry, large or small.

*Manuscript received February 6, 1899.—Secretary, Ass'n of Eng. Socs.

The common and derisive question of the inland Congressman, typical of his constituency, was, "What do we want a navy for, anyway?" and the question went unanswered, or badly and ignorantly answered, because the American people were still in a state of national adolescence; too busy getting their growth. They could not realize that the time was soon coming in their history when, as with trading Britain, sea power must be the mainstay of their prosperity and the bulwark of their defense.

But all this is changed. The epoch-marking year of 1898 saw the sentiment of the nation awake with a bound to the need of a navy and the emergency uses of a merchant marine, and to the fact that we had both navy and merchant marine, small to be sure, but still permeated with the immortal spirit of 1812.

To one who had known the navy and the merchant marine intimately from boyhood, it was a glad sight, last May, to see the men and ships of our national fleet reinstated in their rightful place in the affections and appreciation of his countrymen.

The growth of sea power among leading nations throughout the world is the most momentous fact of current history, and the logic of events has now forced a strong naval and merchant marine policy upon our country. If we would hold our own and take our destiny in hand, we must have a navy and a merchant marine commensurate with our commerce and our geography. Every ship bearing our flag abroad is a knight-errant of civilization and a missionary of trade; but she is far more even than this,—she floats a living element of our defense and of our power to deal justly among nations.

The merchants of England certainly understand some of the axioms of foreign trade. There is one thing at least which we can safely learn from the business men of England without waiting to have it hammered into us by hard knocks in the new field of foreign relations and commerce upon which we are now entering. Anything which tends to the efficient maintenance or betterment of the Royal Navy and British merchant marine commands the lively interest of merchants, manufacturers and engineers throughout that empire; and this with them is a matter of business as well as of patriotism, for it concerns them vitally in their colonial and foreign trade, and, in its reflex action, their domestic affairs. The Royal Navy always stands first and foremost in the care of the British nation, and this for the very substantial reasons just stated. Some such thought and interest must be given our own little navy and merchant marine, if we are to attain and hold our natural and fitting position in international commerce.

Cleveland is far from the sea, you say? No, it is within a short step, and our most inland factory is now rapidly growing nearer to the seacoast in a commercial sense; the ordinary business thought and customs of the last decade are fast becoming a misfit in this respect.

No American manufacturer can now pull his cloak about him and safely say, "I have nothing to do with the sea," for, let him look to it, the influence of the sea and sea power will surely affect him vitally in some manner, and that soon.

How many members of this community are now directly interested in furnishing naval or merchant ship matériel? How many more members are indirectly affected by contracts for such matériel? How many members can say that their business is entirely unaffected by the naval power and merchant marine of this country, by shipbuilding, or by the sea and its trade? Or am I asking these questions a few years too soon? The manufacturers of this country have barely entered the foreign markets, and we have but just commenced to build foreign warships; the time is plainly in sight when we can build not only the fleets which carry and protect our own commerce, but a large part of the fleets of the world. This is not buncombe; it is a legitimate business forecast. It should need no further argument to show that the betterment of our navy and merchant marine is and should be our especial interest.

I have referred to naval and merchant ship matériel; the following table is accurately condensed from "Brassey's Naval Annual," the "U. S. Naval Register" and "The Statesman's Year Book," all of 1898:

Country.	Sea place.	Modern naval ships, over 1000 tons displacement. Built, building, proposed; '98–'99.		Merchant steamers; excluding river steamers and small craft. Statistics of '95–'97.	
		No.	Displacement.	No.	Register tonnage.
Great Britain	1	287	1,810,050	8,522	6,284,306
France	2	129	741,513	1,235	503,667
Russia	3	96	546,112	522	205,649
Germany	4	84	422,549	1,126	889,960
United States	5	77	395,406	5,551	2,183,512
Italy	6	63	330,970	345	220,508
Japan	7	39	205,518	827	213,221
Austria	8	33	125,339	202	146,098
Netherlands	9	39	109,188	172	196,824
Brazil	10	16	44,313	189	75,283
Denmark	11	17	41,107	445	176,845
Argentina	12	12	39,797	75	21,613
Chili	13	9	39,000	42	29,931
Sweden	14	14	33,906	118	93,653
Norway	15	12	25,797	237	262,950

The recent naval increase of the youngest and the oldest nations in this list is remarkable:

	United States.		Japan.	
	No.	Disp. tons.	No.	Disp. tons.
Sea place in 1896	6	......	8	....
Available Navy, January 1, 1899	50	185,381	26	92,362
Building and projected, 1899	27	210.025	13	113.156
Sea place with last additions	5	......	7	....

In addition to the figures above given the United States Navy had, on July 1, 1898, 47 auxiliaries, with a displacement of about 255,000 tons. When our present program becomes effective we shall be a good fifth, and about equal to Germany if we then have a commensurate merchant marine to draw auxiliaries from. Our sea place should be at least fourth if not third, and coming events, now casting their shadows before, will probably force us to take that place from business and trade necessity, no matter how we ultimately decide as to what has lately been called "imperialism." If this be doubted, we have only to study the merchant ship columns of the table and compare these with the naval columns, using business sense and remembering geography.

The figures given for American merchantmen are those of 1895-6; what they will be in 1901-2, when our present naval program and adequate merchant ship laws become effective, is another matter. We may even deduct say 800,000 tons for lake tonnage in making the sea comparison, but can we say how much of this lake tonnage will remain purely lake tonnage in the near future? Already (and before Canadian canal improvements that are surely coming soon) a considerable proportion of the small lake craft are in winter service at sea. This is a natural and perfectly feasible movement, sure to increase.

Our recent disagreement with a sixth-rate foreign power has shown some lines of needed improvement in our naval matériel: Water tube boilers are here to stay; there will be a minimum use of wood, and that used will be non-inflammable; cruising ships will be wood-sheathed and coppered; "nurse ships" will be a regular part of every future squadron or fleet; to repair, to coal and water, to receive the sick and wounded and for many other like purposes. The little torpedo boat will cut less of a figure; large destroyers, with sustainable capacity for scouting and dispatch service, will be more in favor. Smokeless powder is a necessity.

Application of rapid fire breechings to heavier calibers and an increased muzzle velocity will be sought and gained in ordnance. Higher squadron speeds and manœuvering powers will be sought, resulting in more uniformity in fighting ships.

A cloud of details in construction, ordnance, armor, steam, hydraulic, pneumatic and electrical engineering and equipment has now, by experience, been condensed into the proof-liquor of practice, or blown away as experimental vapor; the short squall has cleared the atmosphere, and we shall have fewer "frills" and more solid fighting sense in the matériel of our warships, though the latter has always predominated.

Our naval matériel is now second to none in quality; it will be still further improved and its quantity will doubtless be brought up to our necessities, for the reasons stated.

It is easy to show figures and facts and make arguments in support of our naval matériel, for general engineering knowledge and public appreciation are now, happily, in a state to receive and understand the facts; but it is far more difficult when we approach the subject of naval personnel, for this still seems to us unknown.

To be sure we have heard about the "man behind the gun"; the "poor devils in the fire room"; the "marines at Guantanamo," and there are two or three names of individuals which have now become household words. But what do we know of the 1327 regular commissioned officers of the navy on the active list, July 1, 1898, as to their effective relations to each other, to the warrant and enlisted force and to the matériel? I venture to say that we know practically no more than we do about the personnel of that questionable fleet which operated against Troy. And yet this body of officers constitutes the most important part of our navy; they are its "gray matter" and vital force; without them our famous fighting ships would be but painted toys upon a painted sea, and our merchant marine a babe unswathed. Whatever affects the personnel affects the navy in head and heart; whatever tends to improve the personnel strengthens the navy more than battleships. What better proof can we have of this than was furnished us on July 3 last? The failure of the Spaniards to put up a better fight and race was not due to lack of matériel nor lack of bravery; it was distinctly due to lack of unanimity, organization and training in their personnel. And this is directly chargeable, not to the Spanish navy, but to the unspeakably foolish and ignorant policy of the Spanish Government in failing to organize and train its brave naval personnel on a modern basis and in the light of modern progress. The Spaniard provided himself with modern tools and used them with the knowledge of the sixteenth century; he despised the engineer as being beneath the spirit and tradition of that fighting chivalry which once enslaved the world, and he suffered the consequence. The Spaniard could not be a mechanic

himself; he hired foreign mechanics in subordinate positions not homogeneous with his combative force; he therefore perished miserably. The Spaniard can live again if he will, but he must learn engineering and make it a unified part of himself,—there is no alternative but death.

The following table indicates how the personnel of our own navy is now arranged both in corps and rank:

REGULAR COMMISSIONED OFFICERS OF THE U. S. NAVY, JULY 1, 1898.—ACTIVE LIST.

Corps.	Rear-Admirals.	Commodores.	Captains.	Commanders.	Lieutenant-Commanders.	Lieutenants.	Jr. Lieutenants.	Ensigns.	Totals.
Line	7	10	45	85	74	250	76	171	718
Engineers	..	1	10	15	5	75	22	52	180
Marines	..	1	1	2	7	22	30	9	72
Medical	..	1	14	15	..	50	53	28	161
Pay	..	1	12	13	20	20	20	25	111
Chaplains	..	..	4	7	..	7	6	..	24
Naval Contructors.	..	1	1	3	..	11	19	..	35
Civil Engineers....	..	1	1	1	3	4	5	..	15
Profs. of Math's...	..	..	3	4	..	4	..	..	11
Totals	7	16	91	145	109	443	231	285	
Grand total									1,327

The first six corps may be called amphibious; their members are seagoing and also have important duties on shore in regular routine.

The members of the first three corps (line engineers and marines) have duties in charge of considerable bodies of enlisted men; the second three corps (medical, pay and chaplains) constitute the "non-combatants," as the term was used in the old sailing days. The last three corps (naval constructors, civil engineers and professors of mathematics) are purely administrative and technical, and have to do entirely with matériel; their members have no regular sea duties after entering their corps, though most of the constructors and many of the professors of mathematics have served considerable periods at sea as young line or engineer officers.

The marines are that body of web-footed soldiers which has remained on warships since the days of Drake, when all "combatants" were soldiers and sailors were only carried to navigate the ships, not to fight. The marines fill a peculiar position; they have army pay and titles and are the policemen and watchmen of the navy, though on occasion they have promptly shown themselves to

be most anything and everything that happened to be needed at the moment in the purely fighting line. The corps is put in the table with assimilated rank to the other two "combatant" corps for the purposes of comparison.

Now as to the first two corps, the line and engineers:

I feel that my peculiar position as a graduate of Annapolis and an ex-officer of the navy lays upon me, as a citizen, a certain duty in this matter as being one of the few civilians who can speak with intimate inside knowledge of the navy.

In performing this duty I could urge upon you the justice of that cry for relief from antiquated conditions which has come these many years from your professional brethren in the naval service. I have consistently refrained from such action heretofore because, personally, I could not see that any of the several solutions proposed by either the line or engineers would really affect a permanent settlement and relieve our navy from certain long-standing troubles which have handicapped the efficiency of its personnel since the advent of steam navigation.

And now that the "touchstone" of homogeneity is found which can turn all this dross of discord into the pure metal of highest efficiency, I do not speak simply as an engineer and as an ex-officer; I choose the higher and broader ground of the loyal citizen who wishes to see our navy placed where the business interests and necessities of the country require it,—in a state of the highest possible service to the nation.

The present Naval Personnel Bill embodies a solution of difficulties which insures uniform justice to all corps and all individuals; which is accepted and urged by all parties in the navy (a thing heretofore unheard of); which offers a guarantee of permanently silencing the tiresome and narrow bickerings and shell-backed prejudices which have hurt the navy for a generation.

This bill (H. R. 10,403, 55th Congress) may be briefly summarized as follows:

1. Differences have existed, justly or unjustly, between the line and staff in regard to rank, pay and duty which have been a great detriment to the service by preventing homogeneity. These differences have been of late years principally between the line and engineers, because the evolution of the warship from the sailing vessel to the fighting machine has forced the members of both corps to become fighting engineers in spite of themselves, and with duties in very many respects practically similar. The ancient and arbitrary distinction of rank and pay was founded in sea-dog prejudice, and has been maintained in the face of progress until it

has become in these modern times a radical misfit, absolutely senseless and detrimental to efficiency. The differences in rank cause needless incongruities and complications in duty and unjust postponement of promotion; the differences in pay are alike unjust to the juniors of the line and the seniors of the engineers.

Both line and engineer officers actually command men in about equal numbers, and yet there is an antiquated statute which, whatever may have been its merits in old days, now flies in the face of fact and common sense by saying that the engineer officer does *not* "command" his men in working one set of machinery, while the line officer *does* "command" his men in working another set of machinery on the same ship. In trying to explain this idiotic fetich to the uninitiated civilian reason rebels, and one can only state the fact. None but a mind trained from youth to illogical thinking can comprehend it. Some of the situations it produces are equal to those "upside down" affairs of "Alice in Wonderland." It is a veritable hidden cancer in the service, but the Personnel Bill will eradicate it without using the knife. The bill, by certain wise and feasible provisions, amalgamates the line and engineers into one corps.

2. Promotion in the lower and middle grades of the line and engineers has been for years so slow as to definitely reduce the efficiency of the service in addition to causing a great amount of positive injustice to officers in the prime of their usefulness to the country.

Officers are now kept in the grade of lieutenant until they are over fifty years old, and then are rushed with bewildering rapidity through the upper grades to the retired list. This is a foolish way to run our navy. We lose a large part of that vigor, snap and quick decision necessary to the commander of a warship, because men kept in subordination until they are forty-five or fifty years old generally lack these requisites. Unjustly slow promotion deadens ambition, drives many valuable men from the service and greatly handicaps those who remain. It is "penny wise and pound foolish" from an economical standpoint.

The bill, by certain wise provisions for "voluntary" and "selected" retirement, creates a uniform and healthy flow of promotion with justice to all and prevents the recurrence of congested points in the list.

3. The pay table provided by the bill is practically that of the army, grade for grade; it is eminently fair and consistent to the officers and is just to the country.

4. The bill gives rank and pay to the constructors in proportion to the high attainments and responsibilities of that very important corps.

5. The bill gives a much deserved reorganization and increase to the marine corps.

6. The bill gives much needed encouragement to the enlisted force by providing for possible promotion and a uniform retirement privilege after thirty years of faithful service.

Enough has been said to indicate the importance of this bill and its vital necessity in the policy of naval and merchant marine progress in which this country is now engaged.

This Personnel Bill is not political except in the broadest and best sense; it has been well fathered and well thought out; it is approved with practical unanimity from end to end of the naval service; its merit and its desert are unquestioned; it was passed by a decisive vote last week in the House; it should pass the Senate at this session of Congress. Its passage in the Senate depends largely upon the energetic action of the friends of the navy throughout this land and upon their urgent insistence that it should pass.

The very fact that this bill is non-partisan and that it especially benefits no individual politician or political faction throws the bill, to a large extent, directly upon the public-spirited interest of the citizen for its support. It has few enemies, and these are not very active, having no ground but antiquated prejudice to stand upon.

There is, however, a dangerous rock in the course of its smooth sailing to the safe harbor of the Revised Statutes; it may lack sufficient active and urgent friends in the Senate to secure its prompt passage; it may, therefore, die from suffocation and the press of other bills.

If individuals, corporate bodies and the press urge its passage and back up their Senators in urging its passage, the bill will probably become a law within two weeks; if this is not done, our deserving naval officers will be left to suffer indefinitely and the country will miss the homogeneity and efficiency which it should have in the naval service.

DISCUSSION.

Mr. Joseph R. Oldham.—A short time ago I wrote to Senator Hanna and our Representative, Mr. Burton, asking their support with regard to this bill, and received a favorable reply from each. It is gratifying to note that they are in favor of the bill.

At present Great Britain has practically three times the mercantile tonnage of the United States. This was not always so;

shortly before our Civil War we had more tonnage than Great Britain. In 1861 we built more tonnage than Great Britain. Then we were adding more tonnage to our mercantile marine than all the rest of the world put together, and we are now trying to restore it to its original condition. In those days the ships were largely wooden ships. The new type of ship was beginning to gain favor at the beginning of the Civil war. Great Britain saw its opportunity, and its tonnage went up at once. The iron ships would carry from 15 to 20 per cent. more dead weight than the wooden ships. The British went on building very fast, and in a very short time they ran our vessels practically off the sea. Fifteen to twenty pounds of steam was then a common pressure. Compound engines were not heard of.

Great Britain carries 70 per cent. of the freight of the world. Last year we built 60,000 tons of steamships and Great Britain built 150,000. Shortly before the Civil War we carried 70 per cent. of the American exports and imports, and now we carry only 9 per cent. This shows the importance of the Government assisting our mercantile marine, and we shall never get a better bill than the Hanna Bill, which is now before the House.

It is not the mail steamers that make large profits; some of the fast lines pass some years without declaring any dividends. The freights are largely carried in tramp steamers, which make a profit of from 12 to 25 per cent. per annum. While Great Britain has a very large number of tramp steamers, there is not such a thing in the world as an American tramp steamer.

We as a club ought to consider very seriously what Mr. Cowles has said about engineers on sea vessels receiving their dues. We find an engineer and a captain sitting in the same office, but the engineer is always a subordinate. The reason for this is that when the master marine was first created there were no engineers, and he was everything. The master mariner can shoot a man if he is insubordinate, which is something that even the President of the United States or the Emperor of Germany cannot do. There is a glamour about him which the engineer has never enjoyed. The engineers on board vessels have been styled "bloody blacksmiths." This is hard on the engineers, and all we want is that they shall be fairly treated. It is only of recent years that engineers have been given the position of principal officer, and that only in a very few instances. We ought to do all we can to advance the standing of engineers in the mercantile marine and navy, so that they may occupy the positions which their abilities and arduous duties warrant.

Mr. W. H. Searles.—The paper is very timely, as the bill to which it refers is now pending in the United States Senate. The Executive Board of this Club has already instructed its President and Secretary to communicate with our Senators, urging their earnest support of this bill, and these official letters have been sent. Letters from individual members of the Club might appropriately be sent, making similar request.

The table shows a great discrepancy in the tonnage of our navy and mercantile marine compared with those of Great Britain. If our mercantile marine is to grow, as we believe it will under the stimulus of the new conditions which have recently come to our country, certainly our navy should be brought up to a ratio more nearly commensurate with that of the mercantile marine.

As long ago as our Civil War I was in Washington and knew many men who were naval engineers. They were men of ability and fine families, and yet there was much friction between the line and engineer officers. It is time that the source of this irritation be removed, and I believe that the present bill will do all this, and that when it becomes law we shall have only harmony and a much better condition of service than ever before.

Mr. C. W. Hopkinson.—I have been following up the articles by Park Benjamin, published in a New York paper, and I would ask how it has been all these years in the foreign navies as to this difficulty between the officers of different corps. Has the question been solved?

A Voice.—Is it not true that the great decrease in mercantile tonnage was due to the depredations of the "Alabama?" I believe the damages paid for the "Alabama" were $15,000,000.

Mr. Wm. B. Cowles.—It is true that the "Alabama" and "Shenandoah" chased far more American ships from beneath the stars and stripes than they actually destroyed. Undoubtedly the award did not cover everything. It was made as fair as possible, but it could not cover the losses to the American merchant marine which were engendered by fear. Hundreds of American vessels were compelled to change flag in order to make sure of safety on the high seas.

There is one very good reason why the American merchant marine has never recovered its prestige. We were too busy developing our inland resources, in railroading and in following up what the railroads brought to us, to turn our thoughts to the sea. The conditions are now different. The year 1898 has drawn our attention to the sea, and I believe we shall keep our attention there. This is a new era. This country is going to have a navy and

merchant marine, and we are going to carry our own commerce before long. Park Benjamin objects to the bill because there is nothing like it as yet in the foreign navies. He asks, Why should we make such a change? Simply because it is fitting for us to take the lead in any necessary project involving mechanism, this country being a leader of the world in such matters. Let us look at the other extreme. Spain has a good navy; its guns, in some respects, were better than ours. It has brave officers. The year 1898 proved again that the Spaniard is no coward. But he had a modern tool and he did not know how to handle it. The Spanish Navy has no adequate engineer corps. The engineers were hired men of other nationalities.

This is a live subject in every navy, and especially in that of Great Britain. I believe that this Personnel Bill becoming a law in the United States will help on something similar in the Royal Navy.

The point is that the engineer should have an official position such as his duties, his standing, his education and his training warrant. An engineer fights and commands on board ship just as much as a division officer or the officer behind the gun; everything is done by machinery; even the navigation of the ship is engineering.

Our line and engineer officers have been educated in the same school, side by side, under the same instructors. They are brothers until they graduate, and then the service, in some practical respects, puts them at swords points. The line officer has had most of the theoretical education in engineering, but has not had the practice, and the engineer has had nearly all the theoretical instruction of the line officer, but not the practical training and experience in handling ships and guns. The new bill provides that examinations and some experience be required in each branch for the proposed amalgamation. If the older engineer officers do not desire to take these examinations they need not do so, but can continue doing the same engineering duty until they have served thirty years (most have done this already), then they can go upon the retired list on three-fourths sea pay. Thus one who does not choose to take the examinations, or who feels that he has a "grievance," may retire honorably and take his "grievance" with him out of the active list. Such honorable retirement is certainly a full offset for any possible "grievance" any individual may feel; in fact, there are now many of the older officers in the grade of lieutenant who are looking forward to this as a boon, and will gladly avail themselves of the privilege, giving place to younger men. Homo-

geneity is the main object sought, and the country will get this great benefit cheaply and justly by the bill.

Yesterday the Cleveland Chamber of Commerce took action upon this bill similar to that which our Executive Board has taken. I would like to see the members of this Club do everything they can to assist in the passage of this bill, and I do not think it would be out of place for some one to propose an informal vote indorsing the action of the Executive Board.

THE CHAIR.—It would be quite proper for the Club to indorse the action which the Board has already taken.

MR. A. L. HYDE.—I move that this meeting indorse the action of the Executive Board in the matter of the Personnel Bill now pending. Seconded by Mr. Oldham. This was unanimously carried.

CAPT. J. A. HOLMES (visitor).—I am heartily in favor of the passage of this bill. I am pleased to see that the feeling of jealousy which formerly existed is being rapidly outgrown. It has been my endeavor ever since I have been Master to bring about harmonious co-operation. I hope this bill will go through. I think it will wipe out the ill feeling which has existed.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXII. MARCH, 1899. NO. 3.

THE EFFICIENCY OF THE BICYCLE.

BY ROBERT H. FERNALD, M.E., MEMBER, CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, February 14, 1899.*]

THE object of this paper is to call attention to a few interesting points in connection with the efficiency of the bicycle.

While it has been impossible for the writer to make any extended investigation in the time at his command, yet enough has been done to start the work along this line at the Case School of Applied Science, where no doubt more extended work will be carried on in the near future.

In the present investigation no attempt has been made to treat the bicycle under road conditions, but simply as a machine; and the efficiency tests therefore have been conducted along the same lines and with practically the same apparatus as that used by Mr. Mack, and described in his paper before the American Society of Mechanical Engineers.

The apparatus, as shown by the photograph, consists of a 10-inch I beam, 15 feet long, planed smooth on top, mounted at a convenient height and carefully leveled.

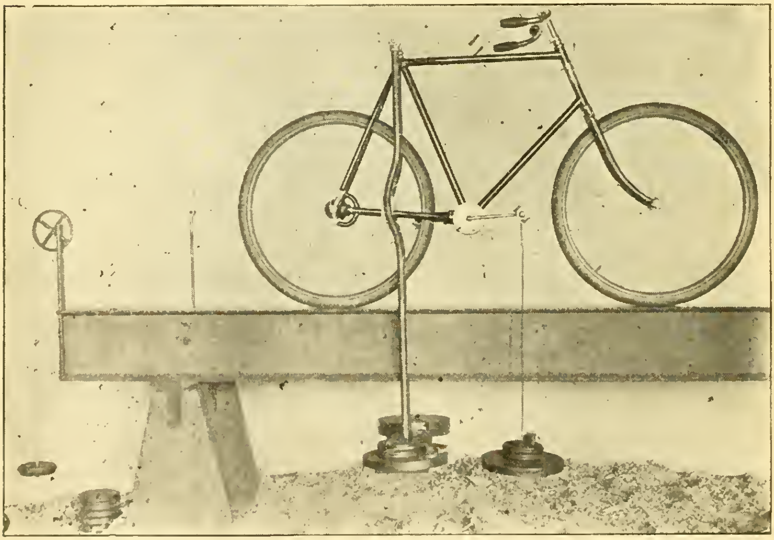
At one end of the beam is fixed a pulley, over which runs a piece of indicator cord carrying a scale pan and attached by wires to the rear axle of the wheel. Suspended from the seat post is a frame made of ordinary inch pipe, and carrying a shelf 3 feet long. This shelf is placed a sufficient distance below the beam to insure

*Manuscript received March 11, 1899.—Secretary, Ass'n of Eng. Socs.

the perfect balance of the wheel when a load of 150 pounds (representing the weight of the average rider) is placed upon it.

The front wheel is maintained in the plane of the rear wheel by means of cords connecting the handle bars to the frame of the machine.

The bicycle is now used as a hoisting machine, known weights placed in the scale pan at the rear of the machine being raised by placing other weights in the pan attached to the pedal. These latter weights, which drive the wheel forward through a short distance, are taken from the shelf, thus keeping the total load on the wheel constant. As weights are transferred to the pedal pan



the balance of the wheel is maintained by adjusting the remaining weights on the shelf.

As the effective radius of the crank varies very slightly for a distance of some ten degrees on each side of the horizontal, it may be assumed as practically constant during this portion of a rotation.

The apparatus thus represents a rider, weighing 150 pounds, sitting upright and gradually throwing his weight from the seat to the pedal, in order to propel the machine.

The circumference of the tire, which enters into the computations, is found by rolling the wheel, with its 150 pounds weight, along the beam, the distance being determined by a mark on the tire.

The efficiency of the pulley must be determined, and the proper corrections made in the indicated weights lifted.

The total efficiency of the wheel is now determined by ascertaining the energy expended in one revolution of the pedal and the corresponding work done in lifting the weight drawn over the pulley at the rear. The difference between the two must be due to the friction of the intervening parts of the machine.

If B equals the circumference described by the center of the pedal pin and P equals weight on the pedal, then B P equals the energy in inch-pounds expended in one rotation of the pedal pin.

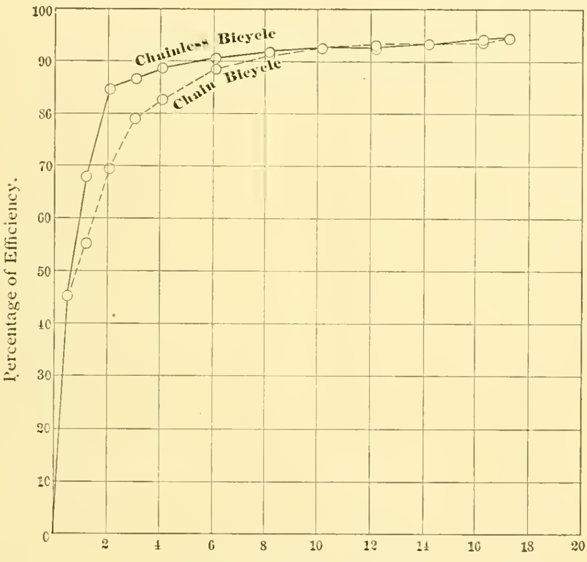


FIG. I. CHAIN AND CHAINLESS BICYCLES.

If R equals ratio of large to small sprocket and A equals circumference of tire, then R A equals distance passed through by the machine for one revolution of the pedal pin.

Letting M equal the resistance overcome, which would equal the weight placed on the pan at the rear of the machine, divided by the efficiency of the pulley, then M R A would equal the actual work accomplished.

The efficiency would then be determined by the fraction $\frac{M\,R\,A}{B\,P}$

It may be interesting to note that it was the belief of the writer that the value of R could not be obtained accurately by the simple method of counting the number of teeth on the two sprocket wheels when the teeth outlines were nearly straight as is the case

with many sprockets, but *only* in the cases where the teeth were constructed according to theoretical principles. After many careful measurements it was found that in every case the correct value of R was given by the simple ratio of the numbers of teeth.

In the accompanying diagrams the curves are so plotted that the ordinates represent the percentage of efficiency, and the abscissas the gross weight lifted at the corresponding efficiency.

One of the first points of interest to be noted is the relative efficiency of the chainless and the chain wheels.

The number of tests made has been too small to determine definitely the relative efficiency of the two makes under the same

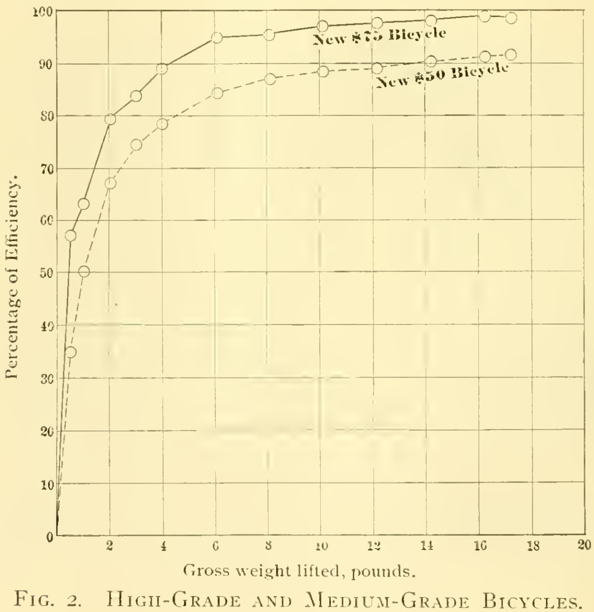


FIG. 2. HIGH-GRADE AND MEDIUM-GRADE BICYCLES.

conditions. It was found difficult to procure exactly the same conditions regarding gear, tires, etc.

Fig. 1 shows the results obtained from two wheels of the same make and grade, these particular curves being chosen as they give practically the same maximum efficiencies.

The full line is the efficiency curve of the chainless wheel, and the broken line of the corresponding chain wheel.

While the maximum efficiencies are practically the same, it will be noticed that the chainless shows a higher efficiency for the smaller loads, which was found to be generally true.

Fig. 2 represents the relative efficiencies of the two grades of wheels turned out by the same company. The two wheels were

obtained directly from the factory, and they represent the work of one of the leading bicycle firms. Both wheels were in the best possible condition. Their relative values were $75 and $50.

Fig. 3 shows some very interesting facts. The upper, or full line, curve shows the results obtained from a special racing wheel, gotten out for the use of a man riding for the company. It was understood that the bearings were specially ground, and everything done to make the wheel represent the best possible conditions. It was very light in construction, and carried $1\frac{3}{8}$-inch tires. The wheel had been ridden only a few hundred miles, and before being tested was specially cleaned and oiled.

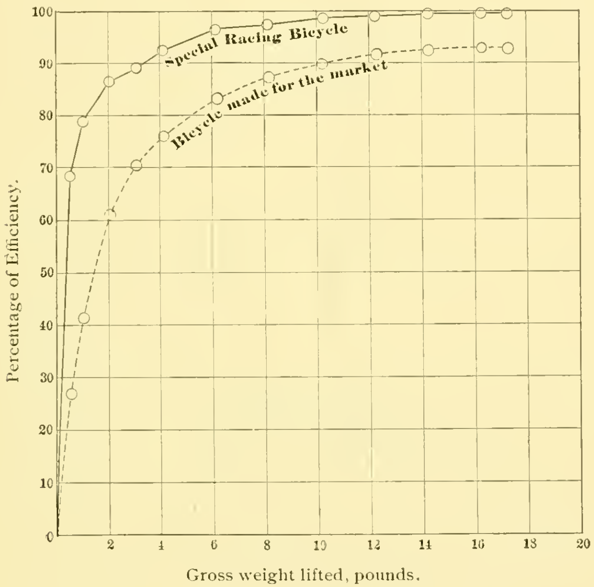


FIG. 3. SPECIAL AND COMMON BICYCLES.

The second, or broken, curve represents the wheel manufactured by the same company for the use of the general public.

Fig. 4 shows the results of tests upon two comparatively cheap wheels. The upper curve represents a wheel of medium grade, and the lower a cheaper wheel, retailing for $25. Both wheels show remarkably high efficiencies.

Fig. 5 represents the results of careful cleaning. The broken curve shows the effect of general neglect, the chain being slightly coated with mud; and the full curve represents the same wheel after thorough cleaning.

In Fig. 6 the broken curve was obtained from a wheel of high grade taken direct from the factory. In this particular wheel the

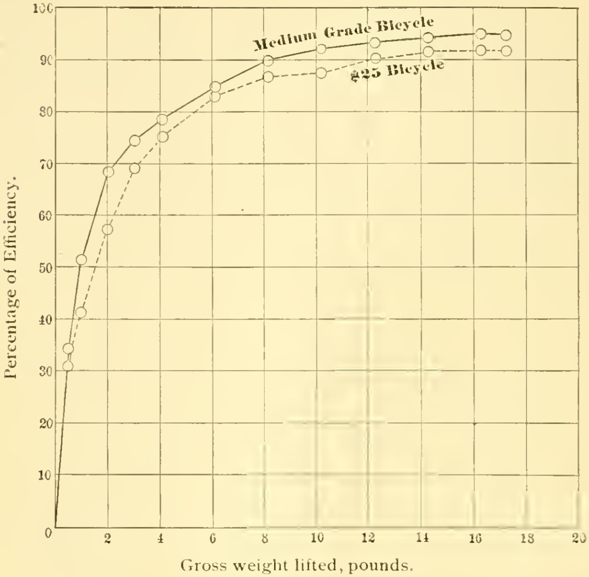


FIG. 4. MEDIUM-GRADE AND CHEAP BICYCLES.

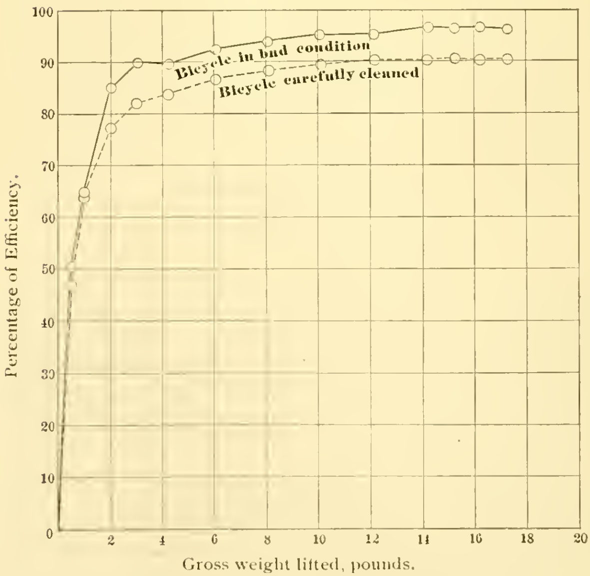


FIG. 5. BICYCLES IN GOOD AND IN BAD CONDITION.

sprocket wheels and chain were apparently rough in finish, and gave a very irregular efficiency, which was far from satisfactory. After having the wheel ridden a few hundred miles it was again placed upon the testing machine, and showed what was expected, the smoothness of action and higher efficiency shown by the full curve.

In Fig. 7 is shown the general effect of oiling a chainless wheel. The broken-line curve was obtained from a chainless wheel that had been ridden for weeks by every one that happened to so desire. The gears had been packed with asbestos paste. At the suggestion of the writer the wheel was taken apart, and it was

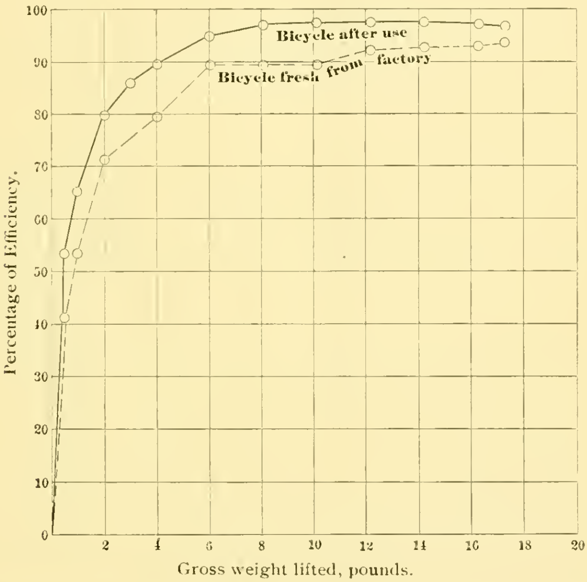


Fig. 6. New and Used Bicycles.

Fig. 8 shows a wheel representing the best practice in bicycle construction and method of protecting bearings, after continued exposure to rain. The wheel was frequently left lying out in the rain for hours, and received no care. The curve shows a remarkable efficiency, and, while the average is far lower than that of the corresponding wheel in good condition, yet it would indicate that the bearings had been but little affected by such usage. The chain,

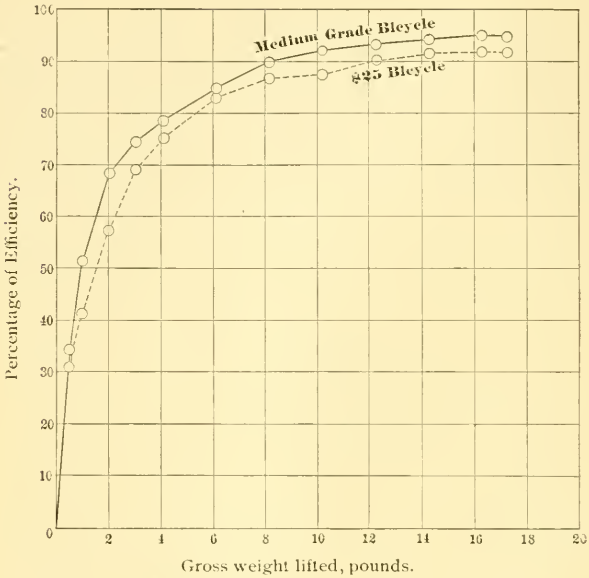
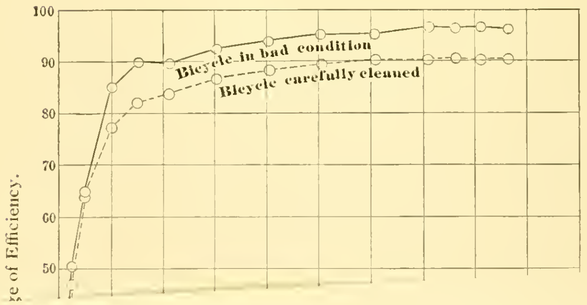


FIG. 4. MEDIUM-GRADE AND CHEAP BICYCLES.



In Fig. 5 the titles of the two curves have been reversed by mistake. The upper line should read "Bicycle carefully cleaned." The lower line should read "Bicycle in bad condition."

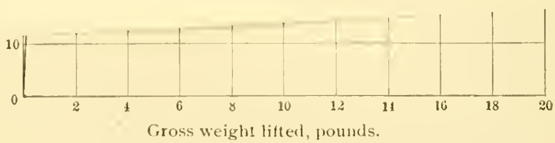


FIG. 5. BICYCLES IN GOOD AND IN BAD CONDITION.

sprocket wheels and chain were apparently rough in finish, and gave a very irregular efficiency, which was far from satisfactory. After having the wheel ridden a few hundred miles it was again placed upon the testing machine, and showed what was expected, the smoothness of action and higher efficiency shown by the full curve.

In Fig. 7 is shown the general effect of oiling a chainless wheel. The broken-line curve was obtained from a chainless wheel that had been ridden for weeks by every one that happened to so desire. The gears had been packed with asbestos paste. At the suggestion of the writer the wheel was taken apart, and it was

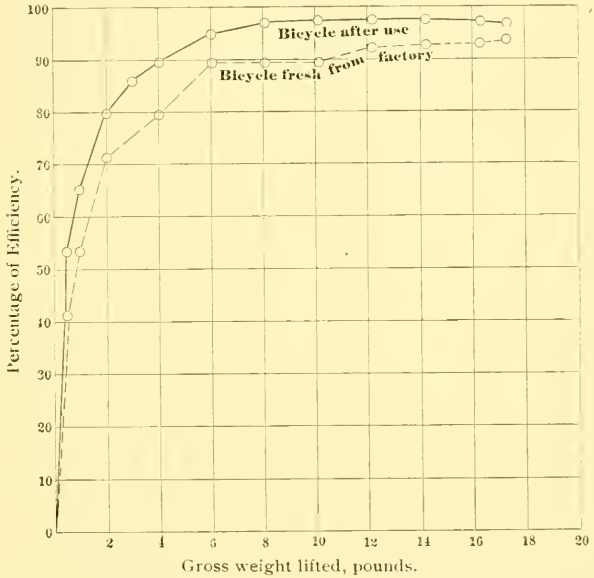


FIG. 6. NEW AND USED BICYCLES.

found, as had been expected, that the paste had been squeezed from between the gears and the cogs were running dry. The wheel was then thoroughly oiled with heavy cylinder oil and again tested, with the results shown by the full-line curve.

Fig. 8 shows a wheel representing the best practice in bicycle construction and method of protecting bearings, after continued exposure to rain. The wheel was frequently left lying out in the rain for hours, and received no care. The curve shows a remarkable efficiency, and, while the average is far lower than that of the corresponding wheel in good condition, yet it would indicate that the bearings had been but little affected by such usage. The chain,

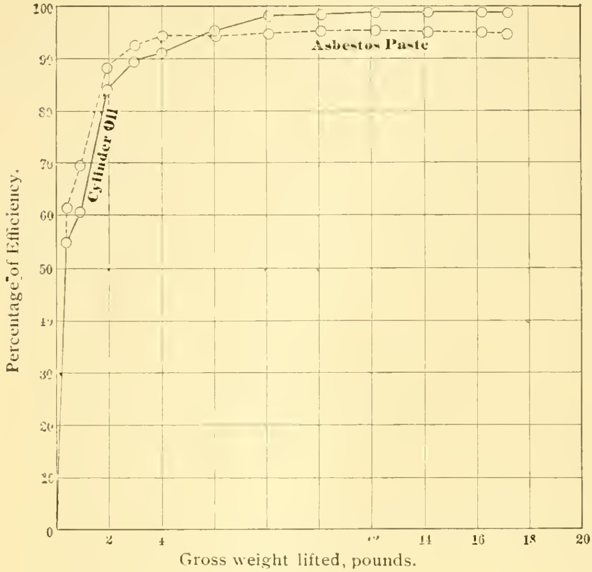


FIG. 7. EFFECT OF OILING ON CHAINLESS BICYCLE.

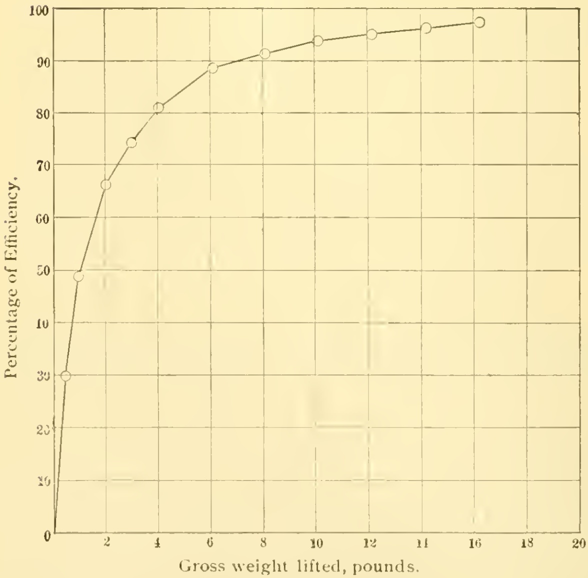


FIG. 8. CHAIN BICYCLE, WITH PROTECTED BEARINGS, AFTER EXPOSURE.

while slightly rusted, was entirely free from mud or dirt, which undoubtedly accounts in part for the remarkable showing.

Besides the tests on general efficiency, a few special tests have been made. Among the results of greatest interest are those obtained from the sprocket tests.

A wheel, very kindly loaned by one of the leading bicycle firms, was carefully kept under constant conditions, with the exception of the change of sprocket wheels. All the combinations obtainable with eight, nine and ten-tooth rear sprockets and from twenty to twenty-five teeth, inclusive, on the front sprocket were tested.

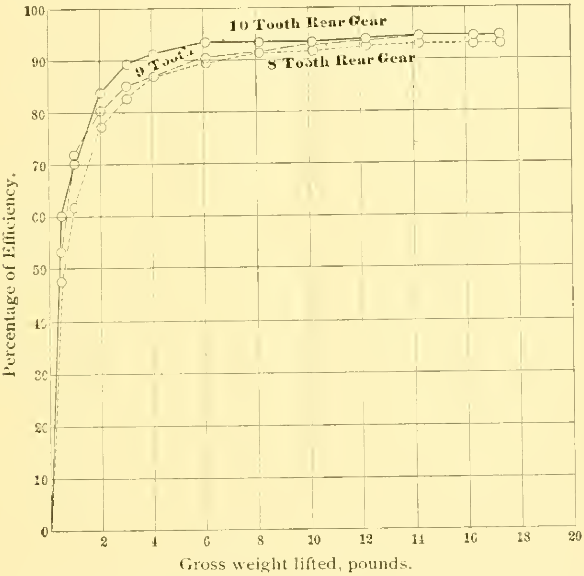


FIG. 9. 20-TOOTH FRONT GEAR, WITH 8, 9 AND 10-TOOTH REAR GEAR.

Fig. 9 shows the results obtained from one such combination, being in this instance the twenty-tooth front with the eight, nine and ten rear. The dotted curve represents the efficiency resulting with an eight-tooth rear. The broken line represents that obtained with the nine-tooth rear, and the full line the corresponding efficiency for the ten-tooth rear.

Fig. 10 gives the average results of the preceding combinations. The dotted curve is the average of the tests with the eight-tooth rear and the six different front sprockets. The broken line is the average of the nine-tooth rear under the same conditions, and the full line that of the ten-tooth rear. While a slight irregularity seems to exist for the smaller loads, the effect for the higher

pressures is very apparent, and shows for the average maximum values that the nine-tooth rear has an efficiency equal to 98.7 per cent. of that of the ten-tooth, and the eight-tooth an efficiency of 98.6 per cent. of that of the nine-tooth. The eight-tooth would then show an efficiency of 97.5 per cent. of that of the ten-tooth.

It has been often asserted that the tire is the most important factor affecting the efficiency of a wheel, and that the amount of inflation would hide all other possible chances for variation in efficiency. While no attempt has been made in these tests to go into this question in detail, yet just at the close of the other experiments a few interesting results were obtained along this line, Fig. 11.

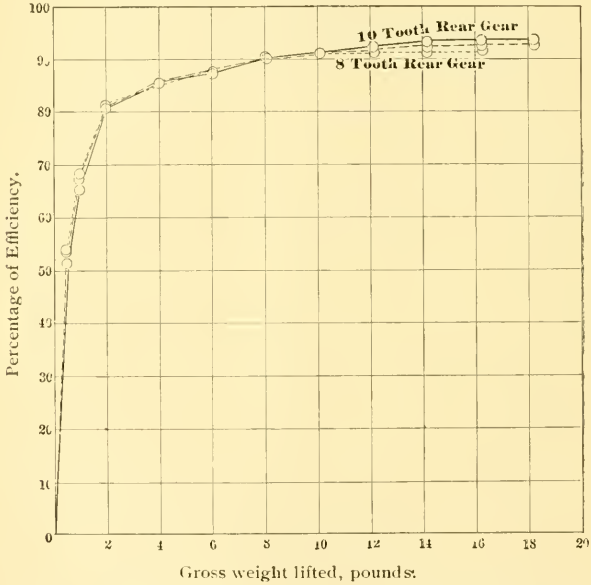


FIG. 10. AVERAGES FOR 8, 9 AND 10-TOOTH REAR GEARS.

All conditions of the wheel were maintained the same, with the exception of the rear tire. In the first experiment the circumference of the rear tire was held at 85 inches under the 150-pound load, this being the same circumference that had been used for all the sprocket tests.

The upper or full-line curve gives the resulting efficiency. The air was then allowed to escape till the tire had a circumference of 84 inches, under the same load, and the curve shown by the broken line resulted. Again the circumference was reduced to 82.5 inches, or until the wheel was nearly running on the rim, giving results as shown by the dotted curve.

The results given in this paper are necessarily very meager, but they give an idea of the many points of interest to be investigated in this comparatively new field. While these experiments have been based on the bicycle used purely as a machine, such results would prove far more interesting and of more general value if actual road conditions were approximated. Such attempts have already been undertaken by one or two bicycle companies and by one or two institutions, and it is hoped that such work may soon be carried on at the Case School of Applied Science.

It is the present intention to make tests with wheels running at different speeds, and also when the wheels are forced to run over

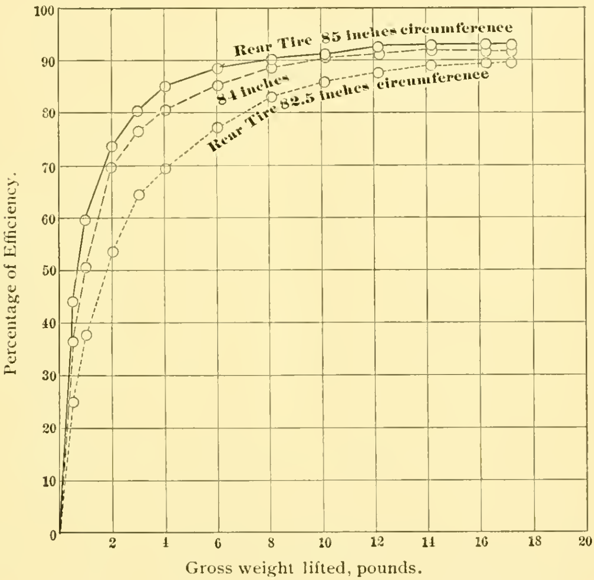


FIG. 11. EFFECT OF INFLATION OF REAR TIRE.

different obstructions made to represent road conditions as nearly as possible, the power required to drive the wheel being determined by a dynamometer.

It is also probable that a pedal dynamometer will be constructed to register the actual force exerted on the pedal by the rider when the wheel is in regular road service. There are many other points of interest, among which are the duration of cone and ball bearings, the effect of vibration of the frame and the efficiency of different makes and grades of tires under increase of speed.

These different points will be investigated as time permits, and a series of results obtained which will be far more complete than those presented in this paper.

DISCUSSION.

Dr. J. W. Langley.—What weight is represented by the abscissæ 2 and 4.

Professor Fernald.—The abscissæ correspond with the weights that are suspended over the pulley at the rear of the wheel. It has been estimated that a weight of 15 pounds suspended at the pulley is equivalent to the resistance of a grade of 1 foot in 12. The heavier the load that the bicycle has to lift the more pressure it requires to drive the pedal.

Prof. C. H. Benjamin.—I have watched these experiments with interest. The efficiency of nearly all machines increases as the load increases. This is especially true of the steam engine. The friction is practically constant, and when the engine is simply running itself the efficiency is zero. This is not true of the bicycle to the same extent, but it is approximately true. The speaker has shown that tests of this character are purely relative, but they illustrate the value of the bicycle as a machine. No matter whether this percentage is the actual efficiency on the road or not, it shows the relative value of the wheels as they are made. Relative to testing wheels under road conditions, the method by which we intend to do this next year is to mount the wheels on rollers, one roller under each wheel, and have a man get on the wheel and ride it. The wheel will be fastened by a cord running back from the rear wheel, and that will be attached to a spring balance which will give the pull of the wheel. He can ride fast or slow, and will get the same effect as traveling on the road, excepting that he will get no further. The power will be absorbed by brakes on the large rollers, which represent the track. The shape of the rollers can be changed to represent different conditions of road. Professor Fernald suggested the idea of putting a dynamometer under the foot of the rider. I think that could be done. The experiments can be made to approximate road service more nearly, but I think the relative values will be just the same as shown in these tests.

Mr. S. T. Dodd.—Professor Fernald was speaking of the proportion of the weight on the pedal to the weight lifted. If 17 pounds lifted corresponds to 75 pounds on the pedal, what weight on the pedal would 1 pound lifted correspond to? About how much weight is there on the pedal for 1 pound lift?

Professor Fernald.—Approximately 5 pounds; from 2 to 5 pounds, depending upon the wheel and the gear.

Mr. S. T. Dodd.—About how much pressure is generally put on the pedal under ordinary conditions on a level road?

Professor Fernald.—I have no idea. In riding up hill a

man puts more than his whole weight on the pedal, but I do not know what would be the conditions on level road. I suppose he would put from 2 to 5 pounds on the pedal.

Professor Benjamin.—When a man is putting 5 pounds pressure on the pedal, as on a level road, he does not care much about efficiency, but when he gets up to his full weight he begins to worry about the efficiency.

EXPERIENCE IN SEWER CONSTRUCTION.

By L. M. Hastings, Member, Boston Society of Civil Engineers.

[Read before the Society, January 25, 1899.*]

Of the several elements which determine the size, character and cost of a sewer system for any community, perhaps the most important is the natural conditions which obtain in the locality to be sewered. The natural conditions here referred to are the slope or inclination of the surface and the character and condition of the soil. The first, by influencing the amount of storm water to be received in a given time, the rapidity with which that and sewage may be removed and the depths at which the sewers are to be placed, is a large factor in determining the sizes required. Much study has been devoted to this matter, and the effect of inclination or slope has been fairly well determined.

The second, as related to the difficulty of excavating and maintaining trenches, in requiring the removal of more or less rock or water, and expensive bracing or special foundations, very directly affects the cost of the work, and varies greatly with the locality. The value of this element is often very difficult to determine. Both these elements should be carefully studied in preparing a scheme of sewers for any district.

It is proposed in this paper to note some experience gained in the city of Cambridge, as bearing on the second element mentioned. The sewers are constructed on the combined system, the diameters varying from 8 inches to 8 feet 4 inches. In constructing the sewers nearly every variety of soil may be encountered, except ledge, which is found only at considerable depths below the surface. The city may be roughly classed in three divisions or zones, as regards the character of soil.

First. The hills and highest lands, which are largely of clay foundation.

Second. The plains and lower land, which are of sand or gravel, usually of a very superior quality, seemingly drift or glacial deposit.

Third. Marsh land and flats adjoining the rivers, and lying at an elevation about equal to that of high tide in the harbor. It may be remarked that the portions classed under the second and third divisions are often underlaid with clay at no great depth from the surface. At the line where the upland and marsh come together

* Manuscript received January 14, 1899.—Secretary, Ass'n of Eng. Socs.

large quantities of water are always found, and as well on the clay, after passing through the overlying sand in deep trenching.

The total area of the city, not including the parks, is 3864.2 acres. Of this, 1206.5 acres are more than 15 feet above mean high tide, 1012.4 acres are between 5 and 15 feet above mean high tide and 1645.3 acres, or about 43 per cent. of the whole area, are less than 5 feet above mean high tide. These divisions or zones would roughly correspond to the classification already made as to soil.

The construction of sewers in the first zone is attended with no special difficulties, the soil being usually firm and hard, with little water; and the sizes of sewers required are small. In constructing these sewers, especially those made of pipe, it has been necessary to be particularly careful in bedding the pipe and in the back filling. The hard material must be removed from the side and bottom, for a space about 6 inches larger than the outside of the pipe, and replaced with sand or gravel, not too coarse, and covering the pipe at least 6 inches above the top. In ledge work the same course should be pursued. This treatment is usually sufficient to keep the pipe from fracture. If the material is very hard and difficult to replace, or soft and liable to unequal settlement, it will be better to bed the pipe solid in concrete.

From 1871 to 1876 large quantities of cement sewer pipe were laid by Cambridge, mostly in this zone, and without special care as to bedding the pipe in gravel, etc., the work being done by contract. Numerous failures of the pipe resulted, due partly to the inferior quality of pipe used and partly to the method of laying.

All pipe now used in this city is of the "Standard Akron" or "Portland Stone Ware Company" make, subject to the usual inspection, and usually of standard thickness. Practically all the sewer work in Cambridge is done by day labor.

A limited amount of "double strength" pipe has been used, but my experience here would seem to indicate that in situations where the best standard pipe will fail the double strength would often prove deficient; and so the standard pipe, reinforced with concrete or brick, has been adopted. Unskillful work in bedding and packing the pipe, not keeping the sheeting drawn in advance of the refilling, and unequal ramming are common causes of a provoking failure in otherwise good conditions. The work of the steam road roller as an engine of destruction must also be considered in some conditions.

The difficulties encountered in constructing sewers in the second, or middle zone, are much greater than those found in the first. The soil is loose and porous, and frequently large quantities

of water are encountered. The sizes of sewers required are also larger for this zone, rendering the general cost much greater.

For sewers having sizes above 18 inches the materials mostly used are brick and concrete. In the early days a favorite form was the "half-barrel," with a circular invert, straight sides and covered with flat stones from a slate-stone quarry. A curious fact noticed about this form is that the bottom courses were laid without cement, and that the slate-stone covers have shown in many cases evidence of deterioration, a species of rot or softening of the stone making it liable to break and fall in.

Where the material is suitable, one of the most satisfactory combinations of materials has been found to be a concrete invert with brick arch. Three samples of this type are shown in Figs. 5, 8 and 14.

The concrete in the invert of Fig. 5 is made of Hoffman cement one part, sand two parts, screened gravel four parts, the sand and gravel, of excellent quality, being found in excavation. The trench was dug to the form required for the invert; the forms were covered with zinc and well greased, and, after the forms were set, the concrete was rammed in a plastic condition in place. After a proper time the forms were taken out, and the inside then finished with two coats of Portland cement wash. This sewer was 13 feet deep, and cost $3.22 per foot, including slants, manholes, etc.

The sewer shown in Fig. 8 was in shallow digging with soft material, requiring a platform and the side sheeting to be left in place. After the invert forms were drawn a ½-inch plaster coat of Portland cement and sand was smoothly troweled on. The section shown in Fig. 14 was built as a storm water overflow, in much the same way, except for the platform. The depth varied from 11 to 18.50 feet. The average cost, with all appurtenances, was $5.60 per foot. The ease with which the bottom is placed, the greater smoothness and symmetry of the section and the greater economy obtained with this method of construction recommend it very strongly.

By far the greatest difficulties in sewer construction are found in the third or lower zone. Of the 1645.3 acres contained in it, the larger portion are flats, either fresh, as at the Fresh Pond Meadows, or salt marsh, bordering the Charles River. This marsh is composed of a layer of salt much resembling peat, varying from 8 to 20 feet in thickness, resting on a bed of clay or gravel. All this muck is soft, and possesses little carrying power, its chief characteristic being a persistent tendency to yield or settle when loaded. Large tracts of this marsh have been reclaimed, from 3 to

6 feet of filling put on it and houses and streets built. The moment it is filled settlement begins, and a curious thing about it is the length of time during which it continues, especially if new filling be added. A very common amount of settlement is 2 to 3 feet. One street, built on a marsh of this character, and carrying a street railway track, settled for at least fifteen years, necessitating raising the track several times and putting on about 3 feet of additional filling; and it is now below grade. It will be seen that with these conditions the problem of stable and permanent sewer construction is a difficult and expensive one.

As the sizes in this zone vary from the smallest in side streets, or laterals, to the largest in the main or trunk lines, a great variety of design must be adopted. A greater part of the sewers must be carried on a pile foundation. This at once introduces a new element of danger; for the material at the sides is soft and possesses little resistance, and, the bottom being on a firm, unyielding base, the tendency to failure from loading the top is greatly increased.

Pipe sewers, unless heavily reinforced, have repeatedly failed. Fig. 1a shows a 10-inch pipe so laid some years ago. This was found cracked and broken from settlement of the material. It was relaid as shown in Fig. 1. Ten-inch ring pipe was used, bedded in concrete, and a brick arch turned over it. Fig. 2a shows a sewer which stood for some years. The street was resurfaced and rolled with a steam roller. In a short time a stoppage was reported, and the entire length of sewer was found crushed. It was rebuilt as shown in Fig. 2, with 15-inch ring pipe laid in a wooden cradle with a brick arch. Fig. 3a shows the construction of an 18-inch sewer. This was built before the street was fully filled. The filling, which was excellent material, was carefully placed, so as not to disturb the pipe. The street was afterward paved with Telford pavement and rolled with a steam roller. After a few years this too was found collapsed and broken, and also some 15, 12 and 10-inch in the same street. This was rebuilt on the same foundation as shown in Fig. 3.

In one case a sewer was put in a street which, while originally soft, had been filled and traveled over for some years. Part of the sewer was on piles of form similar to Fig. 2a. After the sewer was constructed more filling was put on the street. The result was fractured pipe and a clogging of the sewer. It was rebuilt as shown in Fig. 10.

Figs. 6 and 7 show sections where great stability seemed necessary, and where a double line of piles was driven, not opposite each other, but "staggered" like rivets

In pile foundations it is best not to place long stringers on the heads of piles, owing to the difficulty of driving them in line and cutting them to grade. Much better work can be done by using cross-caps spanning two piles. These caps should be of hard pine, as the softer woods are sometimes injured by the great pressure on the heads of the supporting piles.

In Fig. 6 a heavy 4-inch platform was laid on the caps, making a shallow foundation, and so avoiding about 10 inches of wet digging, as necessitated by Fig. 7. In this, however, opportunity was given to use up old 2-inch and 6-inch stock on hand.

The section shown in Figs. 9, 11 and 12 have the same general features for foundation, but with brick construction.

The sewer shown in Section 13 was built under somewhat peculiar conditions. While the locality was some distance from the Charles River, the filling material used in making the land was unusually coarse, mostly oyster shells. Through this the water rose and fell with the tide. To pump it out was expensive, and to stop it almost impossible. Three x 8-inch spruce stock was milled to the exact bevel required, and as many were spiked together as would make a section as large as could be handled on the bank of the trench. After the piles were driven, the girder caps bolted and cradles fitted, this section was easily landed in the trench, and rapidly built up by spiking additional strips in place; any slight deviation from the form being corrected by thin wedges placed at the front or back of the strips. This sewer was built in 1882, and is now perfectly sound, as shown by a recent examination.

Fig. 16 shows a combination of separate sewers and storm water drain, laid in the same trench and carried by the same foundation. The material is 5 to 6 feet of filling, and about 12 feet of mud and a sand or clay bottom. The trench is first dug, piles driven and the underdrain laid. The piles are then cut and capped and the platform laid. The separate sewer is then laid in and covered over with concrete. Branches are put in every 30 feet and carried to the sheeting, which, of course, is left in place, being cut above the top of storm drain. The plank at the end of the branch is partly drawn, so that it may readily be connected later to the house drain. The trench is then filled to the grade of the bottom of the storm water drain with gravel well compacted. Upon this the concrete and brick drain is built as shown. Slants are inserted at intervals of 30 feet, as in the separate sewer also.

The proper construction of tide outlets is one which requires some care, simple as they usually are. Extending from the tide gates to open water at the discharging points, and subject to the

action of salt water and ice, they are usually built of wood and held in position by piles. It is sometimes as necessary to keep the outlet down—*i.e.*, from being lifted or moved by ice outside—as it ordinarily is to hold a sewer up and prevent its settlement. Fig. 15 shows the common construction of a small wooden outlet. The 6 x 10-inch sills rest on girder caps bolted in pairs to the piles. As the mud settles and the spikes by which the bottom planks are attached to the sides rust off, unless carried by the sills, the bottom plank in time falls away from the sides. Unless held by the top girders or heavy filling, the box tends to rise at high water. When the sewer is of large size, say 3 feet 6 inches x 3 feet 6 inches and over, the side walls should be stiffened with oak posts about 3 x 5 inches, placed inside the box and notched into the top and bottom plank, spaced about 3 feet 6 inches apart. The side timbers are pinned with tree nails every 2 feet 6 inches. The cross-girders should be notched into the piles, so that, after the bolts rust out, a bearing will still be had on the wood. Unless placed too high, these wooden outlets are very durable. A number of them, in the city, have been built forty to fifty years, alternately exposed to air and water, and are now in good condition.

In sewers which drain low territories, subject to the action of tidewater, automatic tide gates, designed to keep back the water when the tide is high, and allowing the sewage to discharge freely when the tide is low, are an important adjunct.

The gates must fit tightly when closed, especially if the sewers are connected with the Metropolitan Sewerage System, as most in this vicinity are; must be simple in construction and sensitive in action, so as to open freely and not obstruct unduly the flow through them when open.

Many forms of gates and chambers have been devised in England and in this country. For large sewers I doubt whether anything superior to the old-fashioned "barn door" gate, shown on the plate, has been devised. If made of good material, well fitted and hung with composition metal hinges, it is easily operated and kept in order. The construction is clearly shown in the plate. For smaller and medium-sized sewers the most satisfactory gate I have ever tried is shown in the second plate. This is modelled after a gate used in Providence, R. I. The frame of the gate is made of cast iron, with six lugs cast in the back to extend into the masonry and hold it firmly in position. The face of the frame is planed to a true surface, to which the gate is fitted. A 3 x 3-inch heavy angle iron is then bent in the form of a hoop of the exact size of the gate. In the inside of this hoop the wood is fitted. This is made

of $\frac{7}{8}$ to $1\frac{1}{4}$-inch cypress, in two thicknesses, the thickness varying with the size of the gate. The two courses cross each other at right angles, and are fastened with brass screws. To keep the wood straight and prevent swelling it is first soaked two or three days in water, and fitted in that condition. After the gate is made, the rim is then planed to fit the cast iron frame. The hinge lugs are then bolted in place and the gate hung. In smaller gates the iron hoop is dispensed with, and a rubber gasket nailed to the face of the wooden gate. The long link hinges make them very easy to operate for a suspended gate. The link is made of wrought iron, with composition metal bearings. To reduce the danger of leakage, by reason of their being held open by obstructions, clogging, etc., in the gates, they are usually built in pairs,—*i.e.*, with two gates in one chamber. A type of small cast iron gate is shown in the last figure. This gate is useful, but is apt to be heavy, and consequently hard to operate. The lid or flap should be cast as thin as practicable, in order to lighten it.

DISCUSSION.

Mr. George A. Kimball.—I have been very much interested in Mr. Hastings' paper, in which he has so fully described the methods adopted by him in sewer construction, but there are a few points where the opinions of engineers may differ as to the best practice.

Mr. Hastings stated that it was his custom to build an 18-inch sewer with a concrete invert and brick arch. My experience has led me in a different direction. I have always considered it better to build this sized sewer of pipe reinforced by concrete rather than to use brick and concrete. I think there is some danger in using concrete for the invert of sewers, although I admit that if built of the Portland cement according to the modern methods it is much better than by the old style of construction. I have seen cases in old sewers where the acids which are carried in the sewage have eaten the inverts.

Mr. Hastings.—Mr. Kimball's points are well taken and important. I think, however, his fears are groundless, for the surface of the sewer I have built with concrete invert has been *very much* smoother than any pipe sewers, principally on account of their being no joints as in pipe sewers. I have never seen a smoother, truer job than was obtained on No. 8 and No. 14. With regard to action of acids on Portland cement, I never yet have seen any such action on the Cambridge sewers, either cement pipe or brick, and some of the cement pipe was pretty poorly made, rendering it peculiarly subject to any such action if there was any.

Mr. T. Howard Barnes.—I would like to ask Mr. Hastings if he knows of any specific case of failure of pipe due to the action of steam road roller?

Mr. Hastings.—I can now recall two cases,—one referred to in the paper in speaking of Fig. No. 2 a and No. 2. In this case I lay the trouble entirely to the steam roller. Another case was that of a 24-inch pipe laid in sand about 7 feet deep. The trench was filled up temporarily with the sand and surfaced and rolled with steam roller. On opening the trench to extend the sewer the pipe was found crushed for about 25 feet from the end.

Mr. E. S. Dorr.—I would like to ask Mr. Hastings in regard to single rows of piles for sewer foundation. I have often, from economical reasons, been tempted to use a single row of piles, but lacked the nerve to do so. I would like to ask Mr. Hastings if he has not had more or less trouble in properly aligning the piles.

Also I wish to ask about the manhole for the double sewer shown on Fig. 16,—how the lower sewer can be reached?

Mr. Hastings.—I have never found any trouble in driving piles near enough to a line so that foundation can be safely placed on them. The material is usually soft and the trench nearly excavated before the piles are driven, so that there is practically no trouble in getting a good line by using care.

The manhole is a two-story one, the upper part having a false bottom with cast iron frame and plate iron cover in two pieces. This is calked in place when set, and can be easily taken out when an examination of the lower sewer is desired. This, of course, would never happen when any water would be running in the upper sewer, as it is a storm sewer.

Mr. Alexis H. French.—I have been a good deal interested in Mr. Hastings' paper, as many of the problems are similar to those we meet in Brookline, where we have numerous areas of vegetable deposits from 10 to 50 feet deep, and the surface of some of them as high as 200 feet above sea level. The streets built over them continue to settle for many years, and it frequently becomes necessary to build sewers in these streets while the settlement is in progress. In the deeper deposits it is the practice to build the sewers on timber platforms supported by piling, making the construction strong enough to carry say 10 to 12 feet in depth of earth and resist the strains produced by the continued settlement of the earth on either side.

The most interesting recent case occurred on Beacon street, where there was formerly a "kettle hole" some 300 feet in diam-

eter, filled with a semi-liquid mud from 40 to 50 feet in depth. When the Beacon street improvement was made, the depression was filled with gravel, which had the effect of displacing the mud. About a year subsequent to the filling, a 40 x 60-inch sewer was laid over this place upon a timber platform supported by piling driven through the filling well into the soil below it. The street continued to settle for several years, carrying with it the sewer and platform, without doing much injury to the former beyond producing a lump in which the road detritus tended to settle and from which it was difficult to remove it. Last summer, the settlement then being about 4 feet, the sewer was reconstructed on the old foundation by building up to the proper height with concrete. The work was done this way partly from motives of economy and partly because it did not seem probable that any foundation could be made which would withstand the further settlement of the gravel filling.

Some years since there came under my observation a case where a 24-inch Akron pipe, about 1¼ inches in thickness, was laid on a timber platform and held in place by short timber "chocks," two to each pipe. Most of the pipes were broken into two pieces by longitudinal cracks following the crown and invert.

The pipe was probably too thin, even to be laid in from 8 to 10 feet of sand, but I suspect that the breakage was due to the lack of uniformity in the support furnished by the timber platform and the back filling.

In designing some time since the foundation for a 15-inch pipe sewer, subjected to a light load, piles were driven in pairs at 12 feet intervals, cut off below the water level, cross-capped with hard pine made into the form of skew backs and brick arches thrown from bent to bent; a continuous wall of rubble masonry was built on top of the arches to the sewer grade, the sewer pipe laid and inclosed in brick masonry.

Mr. Desmond FitzGerald.—As the construction of sewers in abnormal positions is in order, perhaps it may not be uninteresting to the Society to hear about a sewer that I once had occasion to build under one of the main tracks of the Boston and Albany Railroad. It will be remembered that a considerable portion of the tracks between the present station and the Providence Railroad crossing is below high water, and that occasionally the tracks are flooded when a particularly heavy rain occurs at the same time with high water. When I was engineer of the railroad, some twenty-five years or more ago, the tracks were often flooded to a depth of 2 or 3 feet with water, which sometimes stopped the trains.

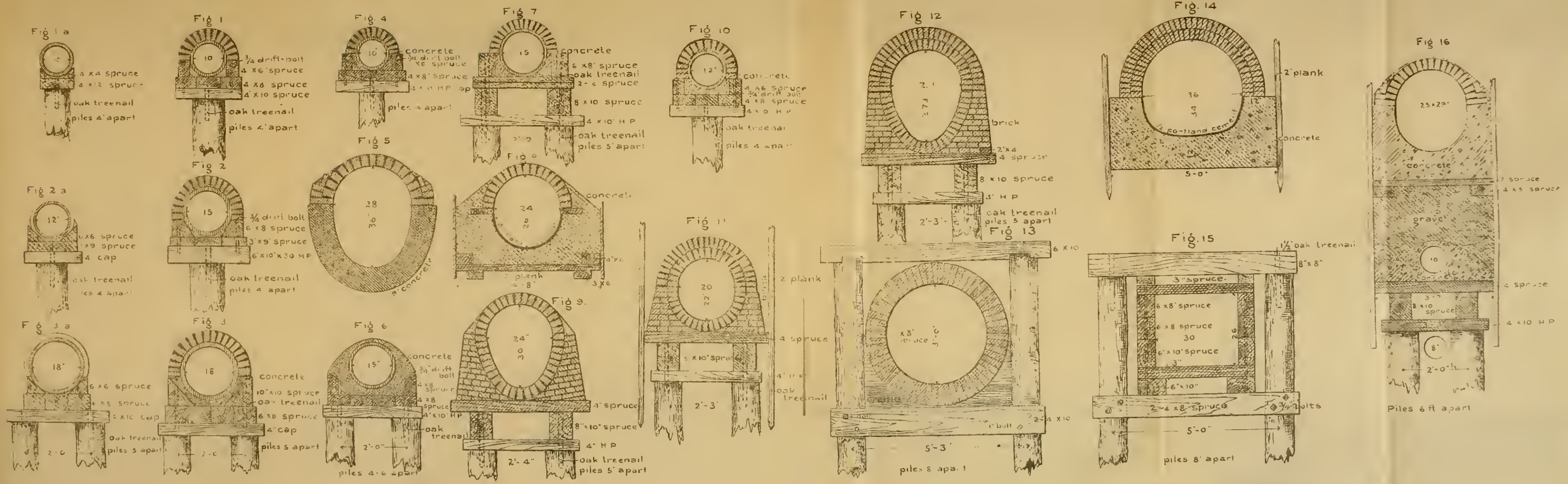
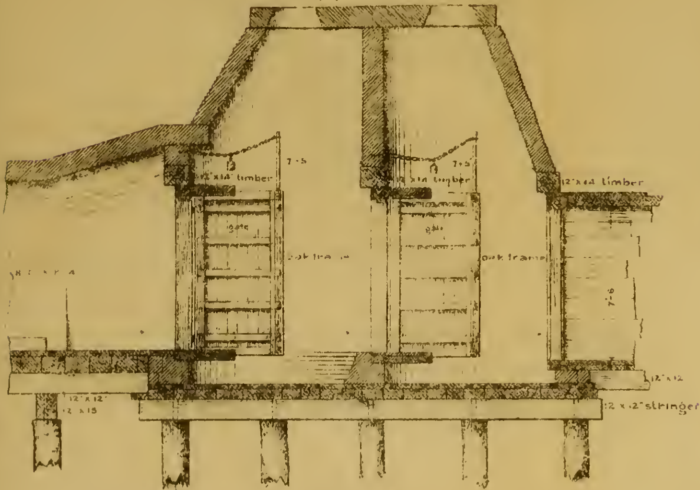


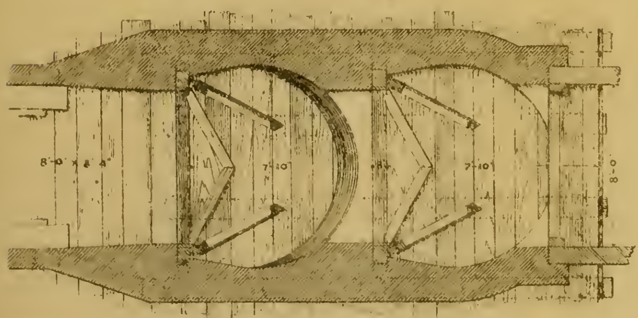
Fig 1 a
4 x 4 spruce
oak treenail
piles 4' apart
Fig 1
¾ drift-bolt
4 x 6 spruce
4 x 8 spruce
4 x 10 spruce
oak treenail
piles 4' apart
Fig. 4
concrete
4 x 8 spruce
Fig 7
concrete
6 x 8 spruce
oak treenail
2 x 6 spruce
8 x 10 spruce
4 x 10 H P
oak treenail
piles 5' apart
Fig 10
¾ drift bolt
4 x 8 spruce
oak treenail
piles 4 apart
Fig 12
brick
8 x 10 spruce
oak treenail
piles 5 apart
Fig. 14
2" plank
36
concrete
5-0"
Fig 16
concrete
gravel
4 x 10 H P
Piles 6 ft apart
Fig 2 a
4 cap
oak treenail
Fig 2
¾ drift bolt
6 x 8 spruce
3 x 9 spruce
6 x 10 x 30 H P
oak treenail
piles 4 apart
Fig 5
28
concrete
24
2" plank
Fig 11
20
2" plank
4" spruce
oak treenail
2'-3"
Fig 13
6 x 10
5'-3"
piles 8 apart
Fig. 15
1½ oak treenail
8" x 8"
3" spruce
6 x 8 spruce
30
6" x 10" spruce
6" x 10"
2-4 x 8 spruce
¾ bolts
5'-0"
piles 8' apart
Fig 3 a
18"
6 x 6 spruce
oak treenail
piles 5 apart
Fig 3
18
concrete
10" x 10" spruce
oak treenail
6 x 8 spruce
4" cap
piles 5 apart
Fig 6
15"
concrete
oak treenail
2'-0"
piles 4-6 apart
Fig 9.
24"
30
4" spruce
8" x 10" spruce
4" H P
2'-4"
oak treenail
piles 5' apart

TIDE GATE CHAMBER FOR 8-0 × 8-4 SEWER.

Vertical Section

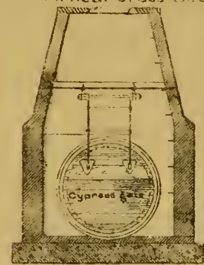


Horizontal Section

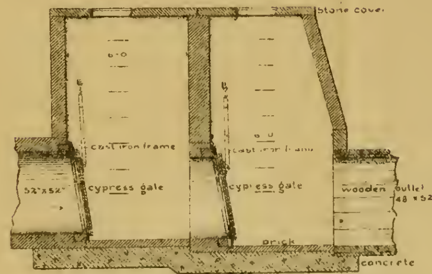


TIDE GATE CHAMBER FOR 52 × 52 SEWER

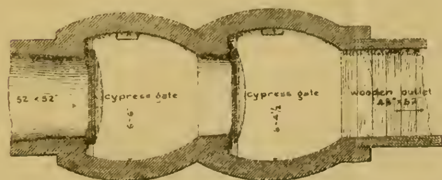
Vertical Cross Section



Vertical Section

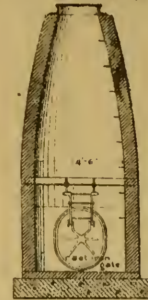


Horizontal Section.

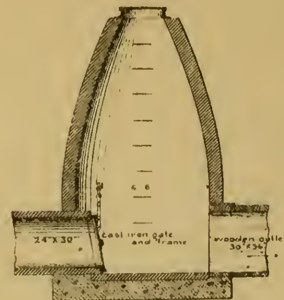


TIDE GATE CHAMBER FOR 24"X30" SEWER.

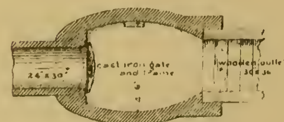
Vertical Cross Section.



Vertical Section.



Horizontal Section.



A large sewer with double tide gates designed by Mr. Wm. H. Bradley was built from South Bay to the elevator; the outlet, as I remember it, was just above low water, and the upper portion was perhaps only a foot or two higher. The sewer was built large enough at its lower end to act as a storage reservoir for ordinary rainfalls, and the discharge, of course, took place at low water. There was very little head room for the sewer under the tracks, and this necessitated putting the tracks almost immediately on top of the brick arch. The sheeting was driven by a machine placed on a car and moved on the adjoining tracks. It is a good many years since this sewer was built, but, as I remember it, there was only an 8-inch ring under the track, and I recall very well, while the arch was still green and when the braces were taken out, seeing the arch rise at the top and crack. The braces were instantly restored and the track laid as quickly as possible on top of the arch, and I have never heard that there was any trouble arising from the construction, as trains have been running over it ever since. I do not cite this case as an example for engineers to follow, but rather as one for the younger members of the Society to avoid. The sewer as constructed certainly affords a large amount of relief.

MAINTENANCE OF THE SYSTEM OF SEPARATE SEWERS AT NEWTON, MASS.

By Stephen Childs, M. Am. Soc. C. E. and Member of the Boston Society of Civil Engineers.

[Read before the Society, November 16, 1898.*]

The maintenance of sewer systems is a subject upon which there is very little published information.

It is eminently useful that the various systems in and around Boston should be maintained at their utmost efficiency, and this result can best be accomplished by an interchange of ideas and suggestions of the various methods now in use. Toward this end the writer has been asked by your committee to give an account of those employed at Newton, not with the idea that they are models, but that mutual benefit may be derived from a free discussion of all methods.

The problem of providing Newton with a system of sewers was one that the growth of the city had long been demanding. It was not, however, until the Metropolitan Sewer Commission, by its plans for a trunk sewer up the valley of the Charles River, gave us the needed outlet through Boston's main drainage works to Boston harbor at Moon Island that definite plans could be made for construction.

Our system is known as the separate system, only house sewage being provided for, and the sizes are therefore small.

Except in two or three cases, where it was possible to get rates of 4 feet in 100 feet, where 6-inch sewers are used, our minimum size of street sewer is 8 inches, and our largest is 24 by 36 inches.

A system of surface water drains which empty into the brooks or river is being built, as necessitated by the development of the city.

The city is composed of nine villages, separated by topography and local interests, each having its own business center and postal sub-station. These cluster around the various stations of the Boston and Albany Railroad and its Circuit Branch, so called, which now is developing three smaller villages.

The city is surrounded on three sides by the Charles River, and is intersected by four main brooks. The valleys of these brooks, together with the banks of the river, are therefore the natural locations for our main sewers, and in the plan for locations

*Manuscript received February 18, 1899.—Secretary, Ass'n of Eng. Socs.

these have been followed as closely as existing conditions would allow.

The Charles River Valley sewer of the Metropolitan system was commenced in 1890, and in the spring of 1891 contracts were let for sewers in the villages of Newton and Newtonville. These sections were completed in April, 1892; but the first house connection was made in October, 1891, so that some parts of our system have been in use over seven years.

Contracts were let for additional sections in 1892, 1893 and 1894, but, by the failure of several of the contractors and the fact that during these years our own men had done a portion of the work, with a considerable saving to the city, it was decided to so continue the work as fast as it was deemed necessary.

In this way eight of the nine villages mentioned have received the benefit of the sewers, and work is now begun on the ninth.

We have at the present time 83 miles of sewers in use, 65 of which are of 8-inch pipe.

For connecting houses with the sewer we make use of T branches instead of Y's. This gives a direct inspection from the "clean-out" at the wall of the house to the sewer, while the Y branch in most cases necessitates an eighth bend, which affords a possibility of solids so collecting that they could not be easily removed. As far as I know, in our seven years' experience, no harmful effects upon the flow of the sewage itself have resulted from the use of T's.

For house drains we use either 5-inch or 6-inch; 5-inch preferred by reason of its scouring better. The minimum rate is 2 per cent., although in some few cases 1 per cent. has been allowed.

As stated, our minimum size of street sewer is 8 inches, and the minimum rate for this size is 0.50 feet per 100 feet; and it seems to us that it would not be safe to reduce it, for in two or three cases, where it was necessary for a short distance to lay an 8-inch sewer at a rate of 0.40 feet per 100, some trouble was caused.

SYSTEM OF UNDERDRAINS.

Under all of our sewers (with the few exceptions where it was definitely known that the level of the ground water was much lower than the sewer grade) an underdrain has been laid. The size necessarily varies, our largest being 18 inches under one of our main sewers, and 4 inches being the minimum. The underdrain pipes are surrounded by screened gravel, and the whole is covered with a layer of bagging to prevent the clay from working down into the drain. This bagging does not rot until the soil

above has become so compact that there can be no tendency for it to settle into the drain.

The underdrains are so designed that they discharge at frequent intervals, either into convenient brooks or the Charles River; and, as they are inspected and kept free, together with the system of sewers, they furnish a continuous outlet for ground water, and are therefore of great advantage, especially in those parts of our city where the soil is compact clay and the level of the ground water high.

As an illustration of these conditions, the northwest slope of Hunnewell Hill is a location where previously it was almost impossible to build. Cesspools filled with ground water almost immediately after being dug, and remained so. Cellars were constantly damp and flooded after hard rains.

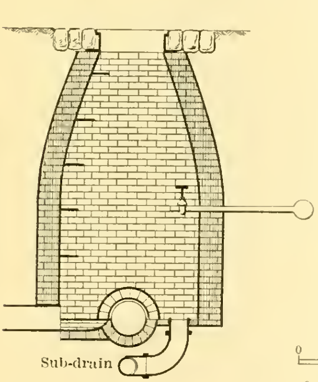


Fig. 1.

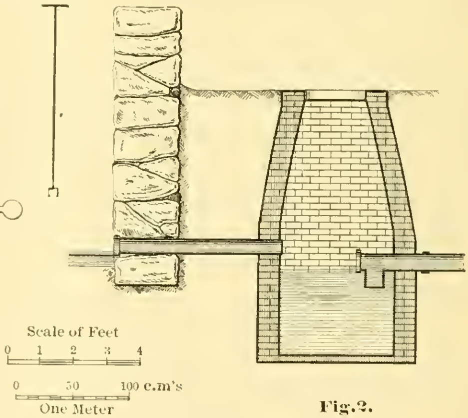


Fig. 2.

Since 1890 this neighborhood has become one of the most thickly settled parts, with desirable residences, in Newton, over seventy new houses having been built. The assessors' books show that the building of sewers and underdrains in this section, comprising an area of about forty-five acres, has increased the assessed valuation $560,300,—a good return on the money invested.

Various plans of inspecting the underdrains at the manholes have been tried, but the one shown in Fig. 1 has been finally adopted, being inexpensive and easy of construction, allowing them to be flushed by inserting a piece of hose in the Y. No mirror inspection is required.

Most of our underdrains flow from half to two-thirds full much of the year, and some of them flow full; therefore little flushing is required.

The system is separated from the sewer pipes, and the opening into the manhole is closed with an iron plate imbedded in Portland cement.

One great advantage of the underdrain is during construction, when it insures a dry bed in which to lay the sewer, making a tight joint possible, reducing the level of the ground water and preventing leaks and the surcharging of sewers.

METHOD OF FLUSHING.

Our pipe sewers are systematically flushed with water from the city mains.

We have never used any of the patented automatic flush tanks for the following reasons:

(1) Their first cost is greater than that of our method.

(2) There is great danger of their getting out of order and either not flushing at all or allowing the flow of only a small stream of water, insufficient as a flush and wasteful.

(3) They need to be inspected almost as often as our flushing manholes are used, and therefore require about as much labor.

(4) In perfect working order they do not give as thorough and efficient a flush.

The flushing manhole used is shown in Fig. 1. A convenient water main is tapped, and a 1½-inch galvanized iron pipe laid into the manhole and closed by an ordinary 1½-inch wheel valve. Rubber-bound wooden plugs, similar to the one shown in the lower left-hand corner of Fig. 3, are then tightly inserted in the pipes opening out of the manhole. To these plugs are attached hook ropes reaching to the surface of the ground. The valve is opened by the key shown, the manhole filled and the plugs pulled out, one at a time.

If this operation does not completely clear any line of pipe, a manhole further down the line can be filled from this water connection and used as a flushing manhole.

A flushing manhole, as shown in Fig. 1, is placed at the summit of all lines of pipe sewer, and in some instances at manholes which are on sewers laid at a flat grade. Two men attend to this work. They have a three-wheeled pushcart in which they carry the different sizes of plugs and necessary tools, and also a set of three mirrors for inspecting the sewers.

The man in charge makes a report at our pipe yard every morning, showing the route to be followed during the day, and also the difficulties, if any found, on the day previous.

We are about to introduce the very efficient system of reports

which has been so successfully used by the city engineer of Medford, Mass.

We have at present 180 of these flushing manholes. The average cost of connecting a manhole with the water main in this way, including digging of the trench, tapping, piping, valve and refilling, is from $11 to $12, but depends, of course, upon the distance of the water main and the nature of the soil.

Our instructions to the men engaged in this work are to commence at the lower part of the system, working gradually to the summit, taking off every manhole cover as they proceed, cleaning out perforations, if clogged, and noting the condition of the line.

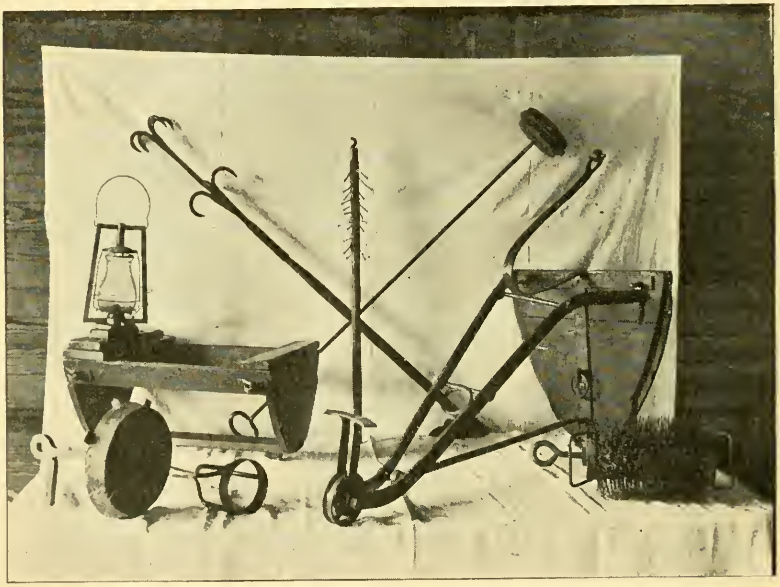


Fig. 3.

When the summit is reached, if the line is found to be clear and the flow unobstructed, the use of the flushing manhole is omitted. If, however, there is the slightest indication of any lodgment of solids the flush is used, and in bad cases one of the men is sent back to make sure the obstruction is removed.

It takes the men about three weeks to go over the 83 miles of sewer in this way.

This is hardly often enough in some parts of the city, and it will be necessary to have additional force when the system is constructed in the village of Newton Upper Falls.

Every one of the flushing manholes is used about thirteen

times a year. The quantity of water used is about 700,000 gallons per year.

Fig. 3 shows a group of implements used in cleaning and scraping sewers at Newton. The wire brush at the right and the jointed rods in the center are especially useful.

The systematic flushing of the smaller pipe sewers keeps them clear and in very good order. We find, however, that this is not sufficient to scour the larger pipe sewers and main lines laid on flatter grades. In the course of a year there collects in these mains, to a depth of from ½ to 2 inches, a quantity of silt, a mixture of sewage and grease with fine sand and gravel, which undoubtedly sifts through the perforations in the manhole covers. Once a year, usually in the winter, this silt is removed by the various scrapers shown in Fig. 3.

The method is as follows: First, a bottle is floated through from one manhole to the next, dragging with it a stout line. Second, a strong rope is drawn through by this line. Third, any one of the scrapers or grapples needed is attached to the rope, and another rope to the back of the scraper. Fourth, the scraper is drawn through and the silt removed in buckets. Fifth, the scraper is drawn back and forth in this way two or three times, or until all silt is removed.

We begin the operation at the top of the flat grades and work downward toward the Metropolitan sewer.

The cost of this work averages $80 per mile.

VENTILATION.

One of the most important factors in the maintenance of a sewer system is its ventilation. In Newton we depend for this upon perforations in the manhole covers and the use of the house stacks, extending through the roof unobstructed by the running trap. The perforations serve as fresh air inlets and the stacks as vent pipes, but the stacks in the valleys undoubtedly serve as fresh air inlets for houses higher on the hills. We have had no trouble whatever resulting from the removal of the running traps.

Our ordinance is permissive in this matter, and owners can retain the running trap if they desire, but we strongly recommend its removal; and of the 3400 houses connected, 2700, or about 80 per cent., are without the running trap.

Many of the objections urged, especially by the average citizen, against a removal of the trap are more fanciful than real. "I don't propose to allow your sewer system to ventilate through my house and the foul odors to escape through possible leaks into

my bedrooms" is the common exclamation of many a man to whom I have suggested the matter.

For a number of years he has perhaps had a cesspool in his yard, and on leaving home some morning after a good breakfast has gone out to see what the so-called "odorless excavator" is doing, and has peered into the cesspool and found the foul material there and a vile odor and gone away to imagine that all sewers are thus vile. Take such a man, as I have many times, to the nearest sewer manhole. Remove the cover and show him the stream of dirty water flowing unobstructedly in the sewer, and ask him if there is any objectionable smell from it. As a matter of fact, there is not in a system designed and operated as in Newton and in many other cities.

At least once in three weeks a quantity of pure water is turned into every sewer, which, together with the water used in the houses, so dilutes the sewage that it can not be objectionable.

Then, again, our plumbing regulations provide for the trapping and venting of each fixture in every house, and the testing of all pipes with the water pressure, which is of vital importance.

By this requirement and the direct passage of local gases and odors to the roof and open air the danger from leaking fixtures is overcome.

There remains the care of such gases as may arise from the decomposition of solids. This small remainder is nearly deodorized and absorbed by the quantity of pure water used in the flushing, the ventilation provided by the perforations in the covers and the free vents carried through to the roofs.

What would be the result if running traps were maintained? In the first place, other means of ventilation must needs be contrived, either by independent stacks, unsightly and expensive, or by some device of ventilating fans at the summits.

By trapping off every house you confine whatever gases are generated in the sewers, making them more like cesspools, and the possibility much greater of disagreeable odors rising from the perforations in the manhole covers. These gases, so confined, may collect in house drains so as to force themselves through the water in the traps (it takes very little pressure to do this), and then, if you have depended on your running traps for protection and have leaky fixtures or poorly vented ones, you are more exposed to danger than ever.

Mr. Frank W. Tower, plumbing inspector at Springfield, Mass., in a paper read at a meeting of the Massachusetts Association of Plumbing Inspectors, held recently in Boston, has given

some very excellent reasons for leaving out the running trap, some of which I will quote:

"First. They act as an impediment to the free scouring and cleansing, as the velocity of flow is greatly checked by the interposition of this trap.

"Second. Every trap, in plumbing work, is a filth-holder; and as sink waste usually contains more or less greasy matter, this is cooled in passing through a drain; and when this trap is reached it readily solidifies and sooner or later causes a complete stoppage of the trap.

"Third. A fresh air inlet or some relief pipe is a necessity at the rear of this trap to prevent air compression. The stoppage of this trap causes the fresh air inlet to act as the waste outlet for all matter discharged into the drainage system unless a fixture in the cellar is lower than this inlet, when the contents are discharged on the cellar floor.

"Fourth. When a fixture is discharged and the trap clear the foul odors generate into the house pipes and are forced through this fresh air inlet, which thus becomes a foul air outlet, and when opening near windows, which seldom can be avoided, causes serious complaint therefrom.

"Fifth. When a good inward and upward draft of air is produced, especially in cold weather, the cold air, passing over or near the water in this trap, chills and frequently freezes the trap contents, and then the filthy waste matter is discharged on the ground near the inlet."

These, together with the others previously stated, are good reasons why we feel that the dispensing with traps is an improvement rather than a source of danger, and the result of our seven years' trial of this method offers additional proof.

One especially good vent for a portion of our system has been gained by permission to connect the drain of the Silver Lake Cordage Mill with their 70-foot smokestack.

The perforations in the manhole covers are a source of some trouble to us in our maintenance work, owing to the quantity of surface water and dirt which thus finds an entrance into the sewer.

If streets could be always perfectly graded and manholes in the center of the streets where they belong this difficulty would be obviated. Dirt pans help this, and have been placed in some of the worst districts. These also prevent children from inserting sticks through the openings, which in one case, where no pan had been placed under the cover, caused a serious stoppage.

The method of keeping from the sewer sand from carriage washstands and straw from manure pits in stables is shown in Fig. 2. A simple brick catch-basin is built and furnished with a tight cover. This catch-basin is so located that a 5-foot length of 4-inch pipe reaches from it to the manure pit. Into the bell of this

4-inch pipe is fitted tightly a galvanized iron grating of about $\frac{1}{4}$-inch mesh. The straw clogs this, and the owner must keep it clear and thus only the water gets away. The seal or trap is furnished by the special T used. This has a cover cemented into the bell end.

Where our underdrains are not laid at a depth of 10 or 12 feet we often find roots have worked through, closing the pipes. A simple and effective method of removing these is by the use of the rod shown in the center of Fig. 3. This rod is simply one of our jointed rods pierced by numerous wire nails. It is forced through into the mass of roots, twisted and drawn back, and usually brings most of them with it. A cutter for removing roots is also shown in Fig. 3.

The total cost of sewer maintenance in Newton for the year 1897 was $2525.54. This total included all necessary repairs, supplies, tools and labor, there being no charge of the water department for use of water. At that time we had in use 77 miles of sewers, an average cost of $32.80 per mile.

DISCUSSION.

MR. T. HOWARD BARNES.—I speak from the standpoint of an experience obtained mainly in connection with the separate system. The Medford, Mass., system differs but little from other separate systems of the Boston Metropolitan district. The minimum size of pipe is 8 inches, laid to a minimum grade of 0.50 per cent., where this is obtainable. As required in practice, we have one line of 0.20 per cent. and several of 0.30 and 0.40 per cent. grades. Six-inch pipe is used only at dead ends of laterals having grades at 22 per cent. or more. The system of flushing, as in the case of Newton, is by discharge from manholes situated mainly at the ends of laterals. Water services are, in most cases, laid into these manholes. Water connections are also laid at intermediate manholes on long, flat grades where the volume of sewage is small.

The length of sewers in use is about 43 miles, and there are 252 flushing manholes or inlets. Of this length about 72 per cent. is 8-inch pipe.

The ventilation of the system is accomplished by means of perforated manhole covers, together with those soil stacks on which the running trap is omitted. This omission is allowable on water-tested work in single systems, but the owner may elect whether or not the trap shall be used. In our practice the trap is generally used, the influence on the part of the plumbers and plumbing inspector being against its omission. Thus far there has been nothing pointing against the policy recommended by the

writer as above stated. I would not, however, expect the running trap to be omitted where the emanations from the stack would be a menace to neighboring dwellings. The plumbing ordinance, which leaves the matter in the discretion of the plumbing inspector, would guard against such occurrences.

One man, equipped with a one-horned pick and a broom tipped with a water-tap key, attends to most of the flushing and inspecting. His instructions are to observe at the first and second manholes in order to see whether any unusual accumulation is washed along by the discharge.

Owing to a lack of water services, some flushing is done by other means. A one-horse water cart, discharging through two 2-inch taps fitted with slide valves and enlarging to 3 inches on the outlet side, is used. This arrangement is very useful also on long lines where intermediate manholes can be filled and discharged. In these cases the plugs devised by Mr. F. B. French, of Woburn, are used to confine the water until its discharge. There are also several cases where a sewer extension has not reached a manhole point, and where access is had by turning up a bend opening into a manhole frame and cover at the surface. Such lines are also conveniently taken care of by the water cart. My observation is that the sudden release of the discharge is of great effect, creating a wave which scours the solids of the sewer. I should have stated that the regular flushing manholes are fitted with flap gates built in at time of construction.

Aside from flushing, the main requirements of maintenance are: the emptying of the dirt pans, gauging of the flow of sewage, care of the regulators at the Metropolitan sewer connections and the adjusting of the manhole covers to the changing elevations of the surface of the street. Considerable time is spent in plugging the holes in the manhole covers, or otherwise preventing the access of surface water.

During 1897 there were in use 225 flushing manholes (counting all, whether with or without water connections) and about 40 miles of sewers. The number of flushings was 2776, an average of once a month for each manhole. The cost was about $550 for labor and team. The total expenditures for maintenance was $1077. Reduced to miles, the cost for 1897 was $13.75 per mile for flushing and $26.92 per mile for all charges of maintenance.

It is found that the sewers need flushing every three, and some of them in summer every two, weeks. This is ascertained by the odor apparent after longer neglect.

This brings up the interesting point of frequency of flushing,

and upon this very point hinges, I believe, the mooted question of the relation of economy between flushing by hand and flushing automatically. By my experience, hand flushing once in twenty-one days will cost as follows, reckoning water at 1½ cents per 1000 gallons (this, by the way, is taken for the sake of comparison with figures by Mr. Andrew Rosewater, in *Engineering News* of May 6, 1897):

Labor per manhole (when supplied with tap)	$1 53
Interest and sinking fund (5 per cent. of $50)	2 50
Water, 9000 gals. at 1½c. per 1000	14
Total	$4 17

If we say (as does Mr. Rosewater) that flushing every day is required, our cost is as follows:

Labor	$32 13
Interest, etc	2 50
Water	2 73
Total	$37 36

In comparison with Mr. Rosewater's figures for automatic flushing, taken from the article mentioned, in which he states that a faucet may be adjusted to discharge 500 gallons once in twenty-four hours, we have,—

Labor maintaining tanks	$6 67
Water at 1½c. per 1000 gals	2 73
Interest and sinking fund (5 per cent. of $100)	5 00
	$14 40

Mr. Rosewater intimates, in the above-mentioned article, that the automatic tank cannot have its tap regulated to flow 500 gallons much more slowly than once in twenty-four hours. This conclusion the writer has heard stated orally by others. If, now, flushing be needed less often than once a day (which I believe), then we must compare the above-mentioned cost of $14.40 per tank (which cannot be reduced) with $4.17, the cost for hand flushing. Even if we say that a discharge twice in twenty-one days is required, or four times in that period, then the cost, respectively, is $5.84 and $9.18. If, further, a higher cost is assumed for water used, then the showing is still more favorable for hand flushing. The cost 1½ cents per 1000 gallons is but little if any greater than that estimated for the Boston Metropolitan district, exclusive of the cost of the local distribution.

One item of maintenance not before mentioned is that relating to the particular sewers or house connections. Thus far, happily, the cost of this item has been very small. Upon about 1700 con-

nections less than a dozen stoppages have occurred, and of these but two were from causes in any way connected with defects of construction. These connections have all been laid by the department; no licensing of drain layers is practiced. Individuals are permitted to do the digging on their own premises. Five-inch pipe is used, connecting at the sewer by a $\frac{1}{8}$ bend and Y branch, and with a 10-foot length of 4-inch XH soil pipe.

A special expenditure for maintenance has been incurred this year,—viz, a systematic scraping of the system. This has been done by a gang of three men, at a cost, for labor, of $336.55. In addition to this, material amounting to about $50 has been consumed. The implement used was a scraper consisting of three disks of four-ply rubber gasket, separated about 10 inches and held by washers on an iron rod, forming what is known to some as a "jumbo" or follower. The disks were cut somewhat larger than the diameter of the pipe. A $\frac{3}{4}$-inch braided cotton rope was used to pull or retard (as required) this jumbo. The leading rope was first pushed down the line of sewer by jointed rods from the flushing manhole to the manhole next below; the water was then turned on, rising back of the jumbo which had been entered into the line of sewer. When a head of from 2 to 4 feet was attained the implement was pulled along, scraping as it went; and the water, escaping along the peripheries of the disks, also assisted in scouring. Considerable sand and gravel were found and removed. There was also removed a skin of grease about $\frac{1}{8}$ inch thick and about 6 inches wide, which coated the sides of the sewers above and below the water surface. The rate of progress was quite variable, depending on the length of straight line and on the amount of sand or other extraneous material encountered.

The greatest daily progress was 8116 feet, the least 1148 feet. The total length was 195,377 feet. The permanent flushing man was paid $2.50 per day, and each of the two helpers $2.00. Rubber boots and oil suits were supplied them. Reckoning $50 for material, the cost per foot was almost exactly 0.2 cent, the cost per mile about $10.50. The sewers had been in use for periods varying from one to nearly three years. The points gained were a knowledge of where street material had entered the ventilation holes in the manhole covers, the removal of several brickbats and chunks of cement and the knowledge that the methods of flushing were maintaining the sewers in good sanitary condition. Aside from street dirt, the largest solid accumulations were films of grease, which were found of about $\frac{1}{8}$-inch thickness at the water line of the sewage. These films of grease were nearly odorless,

and constituted all the greasy matter encountered. Where all the grease from house waste goes to I do not know, unless it is collecting on the sides of particular sewers. We have seen no evidence to show this, but it is a suspicion which I should like to have exploited. Traces of roots of elm trees were found in two cases.

Considerable attention has been paid to the matter of record of maintenance, especially of the flushing. Each flushing manhole is numbered, and has a line along which are entered the dates of discharge and any minutes of interest reported by the flusher. The latter is supplied with a book of daily report blanks. These are posted by the clerk. This record is simple, and has proved very convenient in giving exact history as to care in particular instances.

The gaugings of the discharge of the sewers are taken several times a year. But the total actual sewage being thus far small in comparison with the leakage, no interesting figures are deducible.

Constant care is exercised in order to prevent admission of surface water through ventilating holes of the manhole covers. They are plugged in whole or in part, and in many instances blank covers are substituted for open ones. The best endeavors, however, fail to prevent entirely the admission of surface water in times of slush.

Mr. William Nelson.—I have listened with great interest to Mr. Childs's very carefully prepared paper, and I will take your time for only a few moments in discussing a few of the points set forth. The city of Laconia, N. H., having a population of about 12,000, contains about 18½ miles of sewers constructed on the separate system; arranged with two outlets into a lake having an area of about 12 square miles. The two outlets are 12 and 15 inches in diameter respectively, are composed of cast iron pipes and are each submerged for a distance of about 600 feet. The system is divided into two main lines, with outlets as described, into which empties a system of lateral branches. The longest main is about 3¼ miles from the outlet to the flush tank, and contains one 14-inch cast iron inverted siphon 100 feet long crossing a river, and having a dip below grade of 14 feet. The total cost of construction to date has been $117,149.72, or about $1.20 per lineal foot. This high figure is owing to some difficult and costly work on the main lines. The sizes of pipe run from 6 to 15-inch, in about the following proportions: 6-inch, 60 per cent.; 8-inch, 18 per cent.; 10-inch, 4 per cent.; 12-inch, 5 per cent.; 15-inch, 12 per cent., and iron siphons and outlets 1 per cent. The minimum grade, in feet per one hundred, is approximately represented by

the empirical expression $\frac{2.40}{d}$, where d equals the diameter in inches, although we have one 6-inch lateral 725 feet long laid on a grade of 0.26 feet in 100 feet. This sewer has given no trouble whatever, and is automatically flushed with a 250-gallon flush tank discharging once in about eighteen hours.

The gentlemen who have preceded me did not speak favorably of the automatic flush tank, and, as we have had about seven years' experience with these fixtures, it may perhaps be well for me to take up their defense. The system just described contains eighty-three Rhoades-Williams automatic siphon tanks having 5-inch siphons, and two larger tanks, to which I will refer later. These flush tanks have 8-inch brick walls laid in cement mortar and a 6-inch concrete bottom, and are painted on the inside with a thick cream of Portland cement. Their first cost was $65 each, and the subsequent charge for maintenance has been very light, this year averaging 72 cents per tank, including all labor and material, although in some years it has averaged as high as $3.60 per tank. This reduction in cost of maintenance is owing to close attention to many small details to which I have given a great deal of time. In Laconia flush tanks are used under peculiarly trying circumstances, as the water works plant is owned by a private corporation, and water is sold to the city for flush tank purposes at 18½ cents per 1000 gallons, measurement being made by timing the discharge of a known volume as regulated by a small pet-cock in the supply pipe to each tank. Much difficulty was experienced in setting these small cocks to discharge the proper quantity in the right time, and when they once were set the size and shape of the streams were such that they were very often stopped entirely by sediment in the water. To overcome this I placed upon the discharge pipe in each tank a ¾-inch nickel-plated hose bibb, and fastened to this a phosphor-bronze disk with a hole of the proper size to discharge the required quantity of water under the head, which was measured by gauge at each tank. To fasten the disk to the hose bibb I used a common ¾-inch female hose coupling, in which was placed, first, the disk, then a washer, then a disk of very fine wire gauze, then another washer. This arrangement made a tight job, and it has given perfect satisfaction. The holes in the disks varied in size from 0.0223 to 0.0307 inch, and were bored with small twist drills. Careful experiment showed the coefficient of discharge to be 70 per cent. This arrangement requires attention about three times during the year, and admits of very close and reliable regulation. The hole in the disk gradually enlarges, and a new disk is required about once in two years. The

cost of water used under the excessive rates, as quoted, is about $12 per tank per year. Another detail which gave us no end of trouble was the Portland cement plastering on the inside of the tanks, which was continually cracking off, owing to the action of frost, and allowed the water to escape from the tank as fast as it entered. This defect was remedied by cutting off all the old cement and painting with three coats of thick Portland cement cream. No trouble has been experienced since. One of the large flush tanks, to which I have previously referred, is supplied with water for its operation from the waste pipe of a watering trough, and is designed to flush a short line of 12 and 15-inch pipe laid upon a flat grade. The quantity of water received from this source is much larger than one would suppose, and in this case is sufficient to discharge the tank (750 gallons) about three times per day. The other large tank is a raw sewage flush tank, designed to operate with the natural flow in the sewers, and, in flushing, to clean a 12-inch iron inverted siphon about 171 feet long, crossing a river. To sum up the flush tank question, I will say that in my experience during the last seven years I have found their use, in connection with the separate system, to give cleaner sewers, to allow the use of flatter grades and to reduce the cost of maintenance as compared with the system described by the author.

The city of Laconia has an ordinance which provides that house connections shall be laid by a licensed drain layer who is under $500 bonds for the faithful discharge of his duties. Every connection is laid to a line and grade fixed by the city engineer, and connects with the main sewer by means of a $\frac{1}{8}$ bend and Y branch. The alignment is made straight from the sewer to the inside of the cellar wall, a Y branch being placed just inside the wall with a brass clean-out in the end. No trouble has been experienced with stoppage in the $\frac{1}{8}$ bend. The minimum grade is 1 : 60, and the connections are all 4 inches in diameter. To place, cause or allow to be placed a running trap or any obstruction to the free flow of air throughout the whole course of the drain and soil pipe in Laconia is a misdemeanor punishable by a fine not exceeding $20. The system is thus ventilated through each house connection, and we have found this arrangement very satisfactory. The trouble with roots of elm trees, spoken of by Mr. Childs, has taken place in Laconia, and we have found that this was owing to defective cement joints. To remedy this I have replaced the section affected with extra wide and deep socket pipe which allows a good chance for making the joint, and which, to my mind, represents a distinct advance in the manufacture of

sewer pipe. We now use this pipe in all new work. Within the past seven years we have taken up and relaid about 275 feet of pipe on account of tree roots.

In the maintenance of iron inverted siphons in use in Laconia we have found no especial difficulty, and, contrary to the general supposition, we have found less tendency to the formation of deposits in the siphons than in the sewer lines. In the 14-inch siphon which I have mentioned some sand collects in the lowest point, but is easily washed out by the use of a wooden ball at the end of a rope carried along by the water used in flushing. Notwithstanding the use of automatic flush tanks, it has been my practice to flush both outlets in the spring, and the whole system complete in the fall. This work is performed by five men with a team to carry tools. We put through the wooden ball fastened to the end of a No. 8 braided cotton window cord, which is carried coiled on an ordinary garden hose reel. The diameter of the ball varies from ½ to 2 inches less than the diameter of the pipe for which it is intended, and is made of rock maple. The ball is forced along by water taken from fire hydrants, and in its passage through the pipes produces the best scouring and cleaning action of anything that I have ever seen, the water damming up behind the ball and falling forward by the sides at great velocity. The divided stream, meeting at the bottom of the pipe just in front of the ball, loosens up all deposit and partially floats solids so that the ball easily carries them along to the next manhole. In a 6-inch lateral we have pushed along in this manner, for a distance of 125 feet, an egg-shaped stone measuring 5 x 7 inches. As each manhole or lamp-hole is reached a man with a pole having a strong hook at the end hooks up the line, and, after pulling out on the ground all the line behind the ball, proceeds to let it slowly move to the next opening. Much ground can be covered in this manner at a small cost. The total cost per mile for flushing for the past year has been as follows: For labor $8.24, for water $6.50, making a total expense for cleaning during the year, outside of flush tanks, of $14.74 per mile. Very little trouble has been experienced with sand in the sewers. The worst case was caused by the bursting of a large water main, which carried away about fifty feet of sewer and filled a 12-inch main about half full of sand for a distance of 600 feet. This was removed within a short time by means of a new sand scraper which I had made at a small cost. This scraper is illustrated and fully described in *Engineering News* of April 25, 1895, to which your attention is respectfully directed.

In closing, I desire to say that the subject, as presented by

Mr. Childs, is to me one of the most interesting in engineering, and for that reason I shall have to ask your indulgence if I have taken up more of the time than I was allotted.

Mr. Bertram Brewer (by letter).—The thickly settled and sewered portion of Waltham, Mass., comprises only about one-fifth of the whole area of the city, while the population reached by the sewers is about six-sevenths of the whole. Our system therefore is comparatively compact and easy to maintain. We have but one connection with the Metropolitan trunk line, and that is at the lower end of the city, where Waltham joins Newton. The Waltham system comprises about 37.67 miles of sewers, and the average cost per running foot has been $1.94.

Very few of the sewers have permanent underdrains under them, and temporary ones were used only where absolutely necessary for construction. Without going into the question of the advisability of a complete system of underdrains, I would say that the Waltham sewers have cost much less than would have been necessary had a complete system of underdrains been adopted.

Since 1896 we have been introducing, as rapidly as possible, the method of flushing the sewers by means of valves in the manholes directly connected with the water mains. The pipes are plugged either by wooden plugs or by iron flap valves used to close the outlets while the manholes are filling. When the manhole is filled the valves are raised or the plugs are removed, and the whole orifice of the pipe is suddenly filled with a stream of water which flushes in a very satisfactory and economical manner. The water department also considers this a good thing, as dead ends, where they occur in the water mains, frequently receive a thorough clearing out by means of our regular flushing. We aim to flush all our sewers at least once a month, except in the winter season.

While drain layers are licensed in Waltham, the city has, from the beginning, done all the work in the streets, and in the majority of cases in the private lands as well. As sewer connections are being constantly laid in the season, we are compelled to have a permanent force on hand, and this force is also used a portion of the time on maintenance, which time is, of course, charged to the maintenance account. The sewer system was completed and connections were made in the latter part of 1893, and we have at present about 2215 connections. By careful management, the yearly cost of maintenance for the main sewers has been decreased from $4500 for the year 1894 to $1700 in the twelve months of 1898.

It has been my intention to classify the different parts of our system and to prepare a monthly record of each section, so that a

monthly account of the condition of each part of the sewers will be preserved, together with additional statements in regard to the exact date of the flushing and any other notes of interest. With the coming year I propose to put this into effect. I have, moreover, had a very strong desire, and am glad of this opportunity to express it, that some form for reporting on the various details of maintenance should be adopted. Just as the New England Water Works Association has prescribed a form by which the various facts of interest of the water works systems of the different cities and towns may be preserved in uniform style, so I think the interesting facts regarding the sewer systems of the various cities and towns represented in our Society should be tabulated in uniform style for purposes of comparison and instruction. I should be very glad, indeed, if something were done to bring this about through this meeting and discussion of our Society.

ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC OCEAN
MONTANA
MINNEAPOLIS
ST. PAUL
ST. LOUIS
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
CINCINNATI
LOUISIANA
PACIFIC COAST

Association of Engineering Societies.

Organized 1881.

Vol. XXII. APRIL, 1899. No. 4.

MECHANICAL INFLUENCE IN ARCHITECTURE.

By G. W. Percy, Member of the Technical Society of the Pacific Coast.

[Read before the Society, March 3, 1899.*]

In most popular writings on the subject of architecture and of the origin and development of architectural styles, the causes that are chiefly dwelt upon as affecting and influencing the forms and features of the various styles are, climate of the country, temperament of the people, their artistic tastes, religion, traditions, occupations, etc.

In short, the esthetic and sentimental influences are credited with being the most important factors and the controlling causes in developing their national styles.

Thus we are often reminded that the light and peculiar constructions of the Japanese and Chinese are but the natural representations of the nature and characteristics of these peculiar peoples; likewise, that the massive grandeur and simple severity of Egyptian architecture but reflects the somber, austere and rigid character of the ancient Egyptians and the impressive rites of their religion; that the beautiful and majestic marble temples of Greece are but expressions of the artistic and philosophic nature of the Greek mind, while the round arch of the Romans was introduced for the gracefulness of its lines and purely for decorative effect; that Romanesque architecture was but the result of a different whim, and a desire on the part of the early Christians to cultivate a style different from that of pagan Rome.

*Manuscript received March 16, 1899.—Secretary, Ass'n of Eng. Socs.

When we come to Gothic architecture, imagination runs riot in accounting for the pointed arch and groined vaulting on sentimental grounds, and attributing to the desire to produce picturesque effects such features as the graceful pinnacles, flying buttresses and strong projections, while the lofty spires and high-reaching roofs are supposed to indicate the earnest desire of the soul to follow in the direction of the heavenly index.

While I am quite willing to admit that these and similar sentimental and esthetic reasons have made their impression on architectural styles, more especially on the decorative and ornamental portions of the work, I shall attempt to show that by far the most influential factor in perfecting nearly all strictly architectural forms has been purely mechanical, in devising the best methods of employing the materials at hand, and the means used to overcome structural difficulties and resist natural forces.

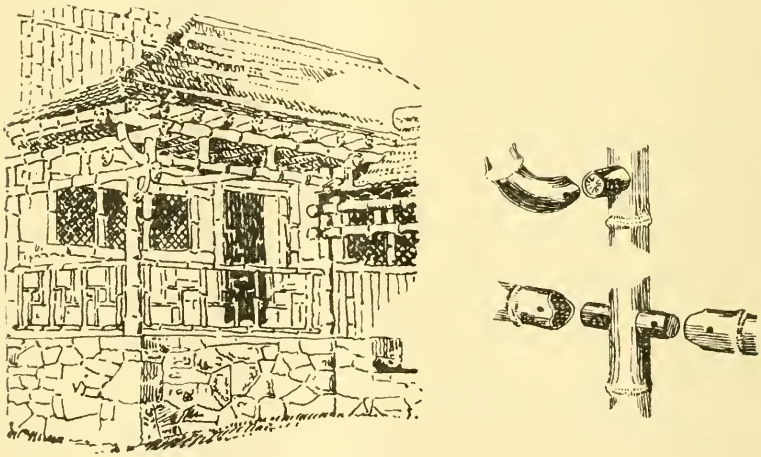


FIG. 1. CHINESE.

In following out this idea while examining historical styles, we shall see that generally the builders used the best judgment, skill and methods at their command, even when it led to changing forms that had become sacred by tradition and association; while sometimes, as in the case of Egyptian architecture, we may find forms and details naturally developed in one kind of material were religiously copied in other materials where they ceased to be appropriate.

So closely has all good architecture in the past followed the rules of good construction that the motto "*Construction* may be *ornamented*, but *ornament* should not be *constructed*," has become

proverbial, and a very able architectural critic lays down this rule of judgment:

"A form which admits of no explanation, or which is a mere caprice, cannot be beautiful, and in architecture every form which is not inspired by the structure ought to be rejected."

Of the surface ornaments applied to their architectural forms by the Egyptians and other peoples I shall have nothing to say in this paper, more than to observe that they consist principally of conventionalized forms of the flowers and foliage of the country where used, and of religious emblems; and that their application is conceded to be due to esthetic and religious sentiments.

As graphic illustrations will show architectural forms more clearly than words can describe them, I have prepared a number

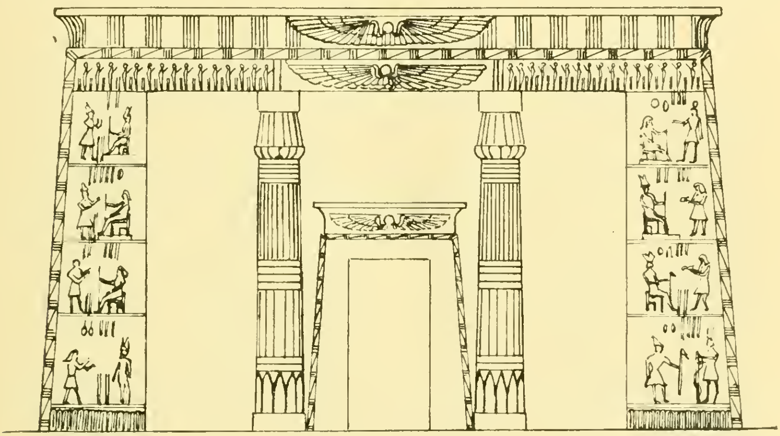


Fig. 2. Egyptian.

of sketches to illustrate my meaning and make my references more clearly understood.

Without wasting time to speculate on the origin and forms of prehistoric architecture, we will refer at once to well-known forms of historic times and work. In Fig. 1 are presented some simple forms of Chinese construction, in which is shown quite clearly the bamboo origin of Chinese architecture.

The properties of the bamboo are well known, and in a country where it is found in abundance, from the smallest twigs to trees 6 and 8 inches in diameter, its great strength and remarkable lightnesss, together with the fact that it is uniformly hollow, with webs at intervals, so that one part may slide inside a larger piece, the ease with which sockets and doweled joints may be made and

secured, and other conveniences of application, were sufficient reasons for making this the principal material for house building, and the forms adopted are such as would naturally be developed in the continuous use of this peculiar material, regardless of the sentiments or characteristics of the people.

In lower Egypt we find quite different conditions and surroundings. See Fig 2. With few trees of any kind and with no stone immediately at hand, the early Egyptians erected their dwellings and other buildings with mud, reeds and bulrushes, which they had in abundance.

On elevated platforms of earth they erected thick walls of mud, placed *in situ,* with layers of reeds and bulrushes to bind the whole together. For greater stability they made the walls battering on the outside, thus reducing the thickness as they approached the top.

To enable them to preserve true angles and proper batter, at the angles of the proposed structure they set up corner posts, consisting of bundles of reeds, neatly tied at intervals with willows or smaller reeds.

A horizontal band of similar bundles of reeds marked the top of the wall proper, and where the thick mud roof should commence. This roof was supported by bundles of reeds laid close together and in turn supported by the walls, and by interior columns of proper strength. These columns also consisted of large bundles of reeds strongly bound together.

To confine the mud or soft clay when applied to the roof, upright reeds were placed close together and secured to the horizontal band. These would naturally bend outward from the pressure of the clay on the inside, and thus produce the graceful and bold cove which forms so conspicuous a feature in Egyptian architecture.

These early structures were plastered on the outside with clay, in the fresh surface of which were easily impressed ornaments and hieroglyphics.

When this people had so far advanced as to build their temples and tombs of granite, the traditional and still prevalent forms of their mud structures were copied to the minutest detail.

Even the massive stone columns in their latest work, in many cases, show very clearly their reed origin, with well-designed capitals of lotus, papyrus and palm, reminders of the flowers and leaves with which the earlier columns were sometimes trimmed or decorated.

The ornaments and hieroglyphics so easily impressed in their

mud walls were now cut with great difficulty in the hardest known building stones.

And this simple style, thus developed, was practiced as long as Egypt was a power.

The monuments of this ancient art still remaining give us on their sculptured walls the best history we have of their arts and sciences.

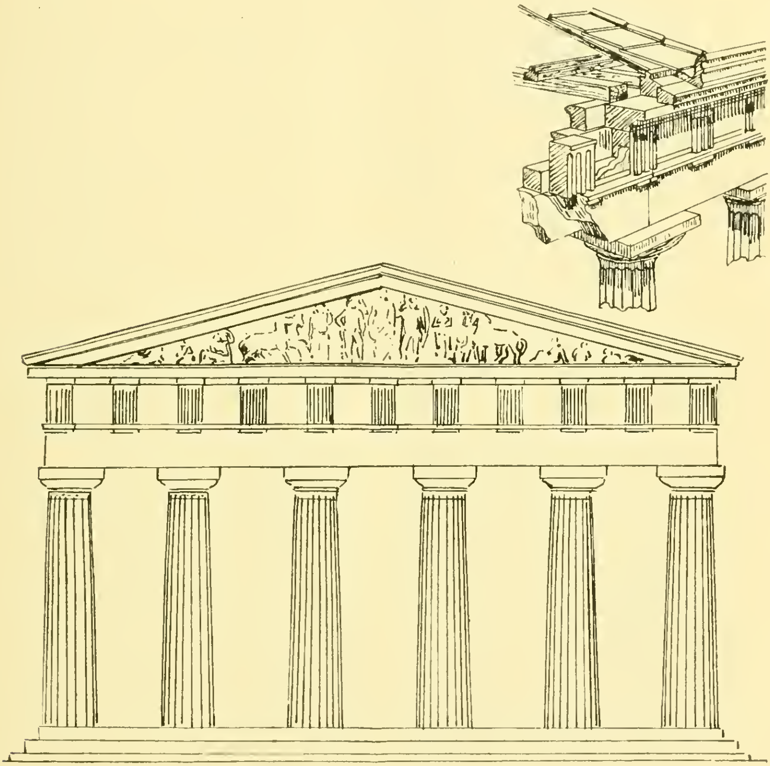


FIG. 3. GRECIAN.

The development of Grecian architecture advanced on quite different lines, and it shows less clearly in the perfected temple the details of its prototype. See Fig. 3.

The early habitations of Greece are generally conceded to have been of wood, and the log hut, with its projecting porch supported on upright trunks of trees, is supposed to have suggested the form of the marble temple and portico.

As Greece abounded in marble and limestone easily obtainable in large blocks, the inhabitants commenced, at an early stage of their development, to build with stone; but, instead of slavishly

copying the forms and proportions of log structures, they did what we should expect of a people who could evolve logic; they devised and perfected forms and proportions more appropriate for their stratified materials.

Instead of making their columns monolithic, placing the natural strata on end, they cut cylindrical sections from the thickness of the layers in the quarry. Then, cutting square holes in the center of each end, they inserted square blocks of wood, in which were fixed axles of a frame, and in this manner the great drum-like sections were rolled over the ground to the site of the proposed structure, where they were wrought to the desired size and exact form, and carefully placed in position. The Grecian columns are much more massive and set nearer together than could have been suggested by wood construction. The spreading cap and broad abacus were designed to shorten the span of the lintel and give it greater bearing surface, at the same time giving level supports for timbers on the outside and inside of the entablature, which should serve as scaffolding and guides in placing the architraves in their exact positions. The architrave itself was made double for greater security from defects in the stone, the triglyphs and frieze to give satisfactory proportions and furnish a protected position for sculpture and ornament, while the cornice projected sufficiently to discharge the water well away from the walls. The low-pitch pediment emphasizes and makes clear the lines of the roof and explains its purpose.

The general form and application of all these parts are strictly adapted to the work they have to perform and to the materials in which they are executed, while the graceful forms of the mouldings, the flutings of columns and ornaments of capitals and friezes, must be credited to the artists' touch after mechanical considerations had produced the general forms.

In Greek work each stone is very perfectly wrought to its proper lines and surfaces, and the blocks are fitted together with the greatest exactness, the abutting surfaces often being polished. Dowels of copper or bronze were inserted in the joints to prevent displacement by earthquakes, and no mortar was used. It was this perfect mechanical work of the Greeks that inspired Longfellow to write:

> "In the elder days of art,
> Builders wrought with greatest care
> Each minute and unseen part,
> For the Gods see everywhere."

In Rome we find still different conditions, and to meet them new mechanical principles are involved. See Fig. 4.

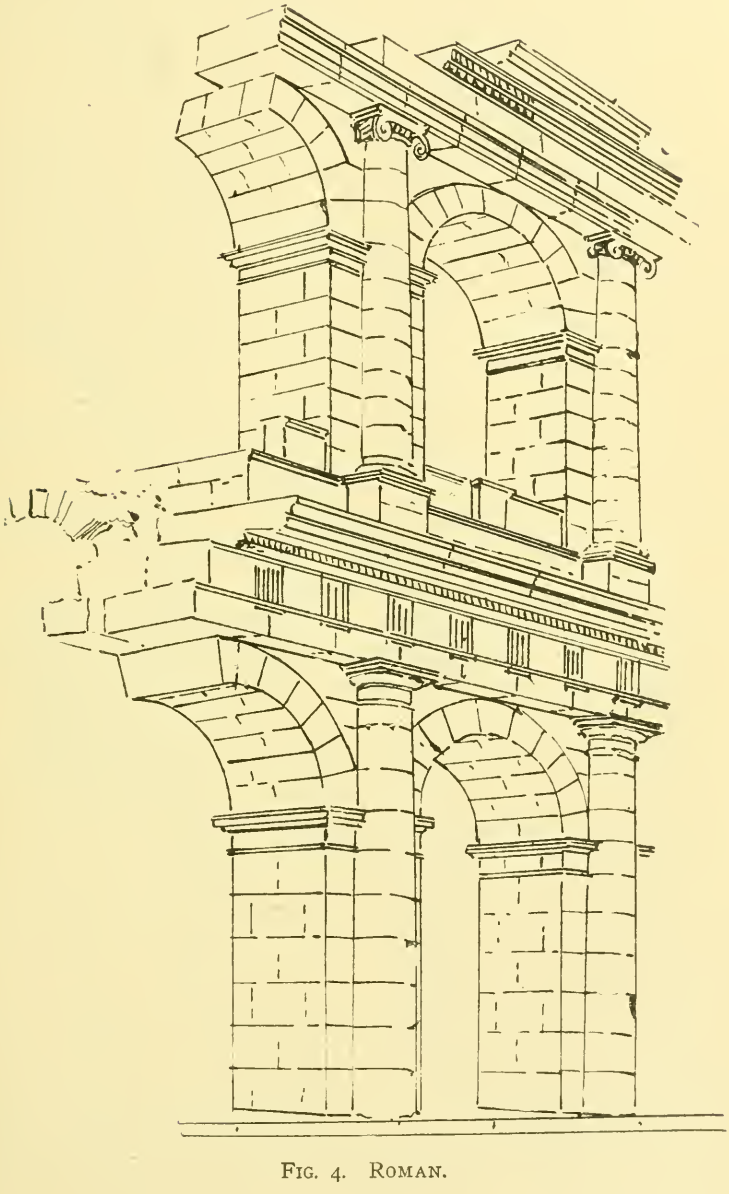


FIG. 4. ROMAN.

Unlike Athens, the immediate vicinity of Rome did not furnish marble or other stone suitable to be used in large blocks. A soft volcanic tufa abounded, with which the early Etruscans developed the semicircular arch as a means of spanning openings instead of the horizontal lintel.

The discovery and first use of the arch can not be positively accredited to the Etruscans.

It was probably in the valley of the Euphrates, where sun-dried and burnt bricks were the building material, that the important discovery was made that a wall of masonry could be safely carried over openings by the use of small wedge-shaped blocks placed with the large ends outward so as to form an arch or bow over the opening. This discovery was destined to play an important part in architecture. In fact, all styles may be divided into two classes, that of the lintel and that of the arch.

The Romans carried the development of this principle to a high degree of perfection, and the round arch became the essential feature of the early Roman construction.

When, at a later day, they conquered the Greeks, they transplanted Grecian architecture to Rome only to decorate their own arched construction.

Instead of the arch being used as a decorative feature of Roman work, it is the vital principle of construction, while the Greek orders were applied literally as appendages, very much as trophies of conquest were carried in their triumphal processions or displayed in their forums.

A Roman monument may be deprived of all its decoration and its apparent form removed without prejudice to its structure; as, in many cases, the Greek orders have been stripped from their buildings for the sake of the marble, and the real Roman construction stands forth in its native dignity, as may be seen in the three great arches of the Basilica of Constantine, the ruins of the Baths of Caracalla and those of Diocletian, and in the better preserved walls and dome of the Pantheon.

The latter building, remaining to this day the largest dome of masonry in the world, is a good example of the Roman method of resisting the thrust of arches with great masses of inert material and not by active opposing forces, the walls of the Pantheon being twenty feet thick and the dome of great thickness of solid concrete, with ribs of brick.

The extensive use of small stones, brick and concrete in Roman work necessitated the use of mortar to fill the interstices

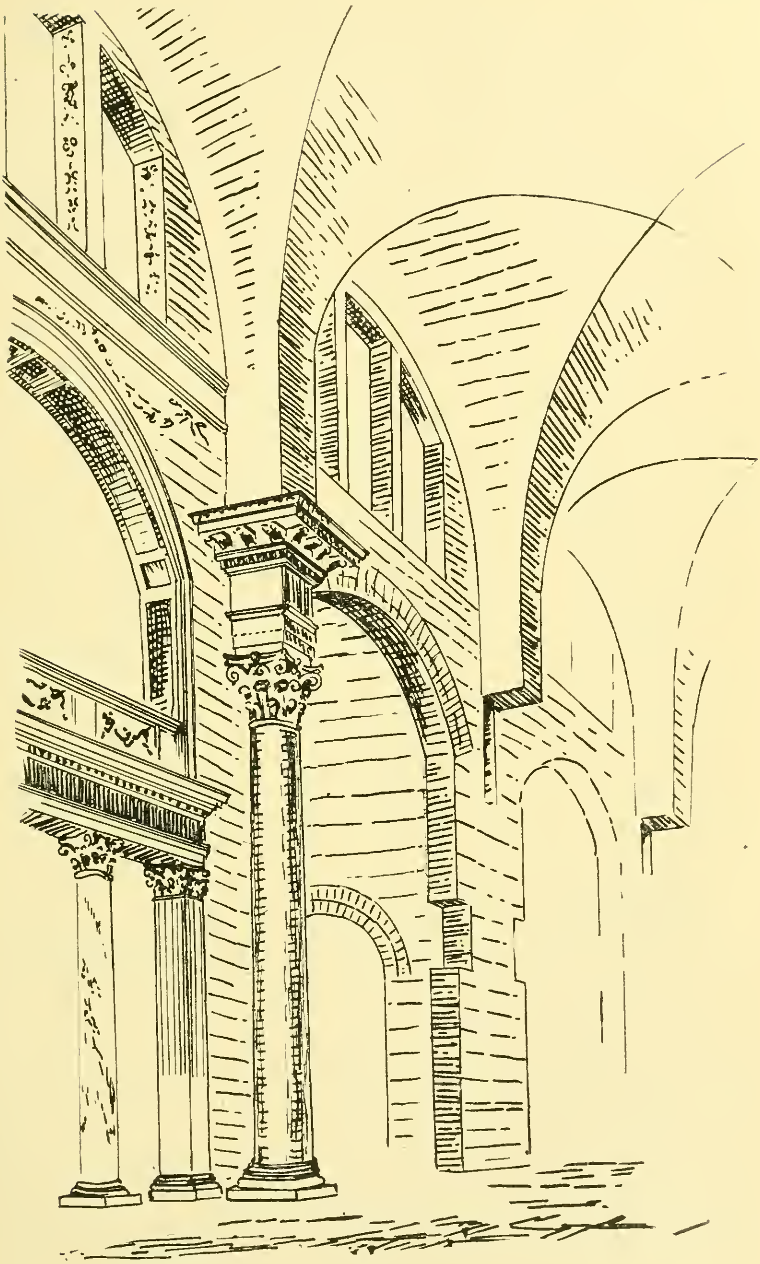


Fig. 5.

and bond the whole together. In this material the Romans excelled all builders down to very modern times. See Fig. 5.

It may appear presumptuous to criticise the Roman combination of arched construction and the Grecian linteled orders, as such work is considered classic and is much copied in modern times. We shall see, however, that the next great change in architectural style, the introduction of the Romanesque, was not the result of Christian prejudice, but of Greek logic applied to building construction. When, in 330 A.D., Constantine established the seat of the Roman Empire at Byzantium and undertook to erect monuments that should rival those of imperial Rome, he employed, for the purpose, Greek architects who had not been completely subjected to the dictations of their Roman masters, and who were allowed to exercise their mechanical knowledge and artistic tastes in erecting the required buildings.

These men, with logical minds, and having not only the benefit of experience with Roman work, but the actual materials taken from the many ruins of Roman work to build with, adopted a new combination, which, as we shall see, was purely structural. See Fig. 6.

The value of the arch, as developed and employed by the Romans, commended itself to the Greek mind as not only the simplest and most economical method of spanning openings, but the only practical method of covering large ones.

They saw, however, that when arches were used to carry the superincumbent weight, the entablature, the essential and most expensive part of the classic orders, was utterly useless, and they did not hesitate to discard it.

Taking the columns, which were brought from Rome, they set them up as the supporting members, and, adjusting capitals with stronger forms and larger abacuses, they turned the Roman arches directly from the tops of such capitals, and by this simple mechanical device was given to the world the Byzantine or early Christian architecture, the progenitor of all Romanesque styles, quite as logical and mechanical in its way as was that of the early Greeks.

The example thus set in the East was soon followed in all parts of Europe. Even in Rome itself, the fallen entablature was allowed to lie dormant and in disgrace for nearly a thousand years.

Dispensing with the classic entablature was not the only suggestion given to the world by the Byzantine architects, for, in their grandest monument, the church of Santa Sophia, we have the

results of the first attempt, on a large scale, to resist the thrusts of domes and vaultings with counter-thrusts.

The church, as built under Constantine, doubtless had a wooden roof and was destroyed by fire about 525 A.D.

Under Justinian it was rebuilt on a grander scale and with vaulted ceilings and stone dome 104 feet in diameter. The ambition of the architect Anthemius exceeded his scientific knowledge of the lateral thrust of such construction, although he planned very ingeniously to resist the thrust on the north and south sides

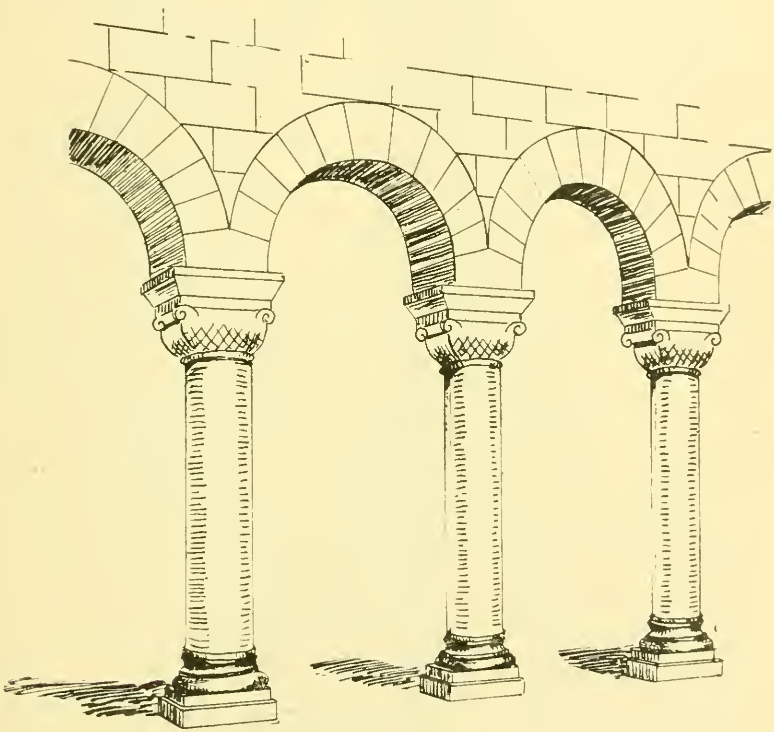


FIG. 6. BYZANTINE.

by means of immense hollow buttresses extending across the side aisles to a distance of 90 feet, and on the east and west sides with half-domes of the same diameter as the central one. These half-domes were again buttressed by smaller half-domes and lateral arches. Still the great dome had not been finished when it gave way on the east side and fell, carrying with it the half-dome on that side.

After this disaster and the death of Anthemius, the superintendence of the work devolved on Isidorus of Miletus, who

strengthened the piers, built buttresses against the east side, threw flying arches from the great side buttresses and filled up the large arches on the north and south sides with small arches in three stories.

With these and other devices, and by using the lightest stone obtainable for the dome, Isidorus succeeded in finishing the building in such a manner that it has stood for over thirteen centuries and in more modern times has been copied many times on a smaller scale for Turkish mosques; and the appearance they present of an attempt to pile dome on dome is the simple result of buttressing the thrust of a large dome with several smaller ones.

As the expedients employed to overcome mechanical failures have often given new and acceptable forms to architecture, so unremedied failures have sometimes been applauded as great achievements. For example, I have often read in magazines and popular newspaper articles great praise bestowed on the builder of the Leaning Tower of Pisa, attributing to him a desire and ambition to erect a monument that should appear to challenge the very laws of nature, and a marvelous degree of success in that direction, when in fact the slightest intelligent investigation will show that the tower was built vertically and commenced to settle to one side before the two upper stories were built. These again were built vertical, when further settlement threw them out of plumb, but of course to a less extent than the lower stories.

Notwithstanding its great inclination, the center of gravity is several feet within the supporting lines of the base, but it is not recorded that a laurel crown was conferred on the architect in recognition of his brilliant achievement.

It was by such failures, and many more disastrous ones, that the lesson of safe building, especially of equilibrium in arched and vaulted constructions, was learned.

During the eight centuries that Romanesque architecture prevailed, there was a growing desire and effort to render churches and other structures fireproof by means of vaulted ceilings and roofs. These ceilings, arched with brick, stone or concrete, often pushed out the massive walls and the building collapsed.

To prevent this, plain, square buttresses were built on the outside to assist the walls in resisting the thrust of the arches. These buttresses, often built after the defects manifested thmselves, soon became conspicuous in the designs and therefore a feature of the style.

As the ambition of the Church seemed to run to larger and higher edifices, the difficulties in resisting the thrust of these inte-

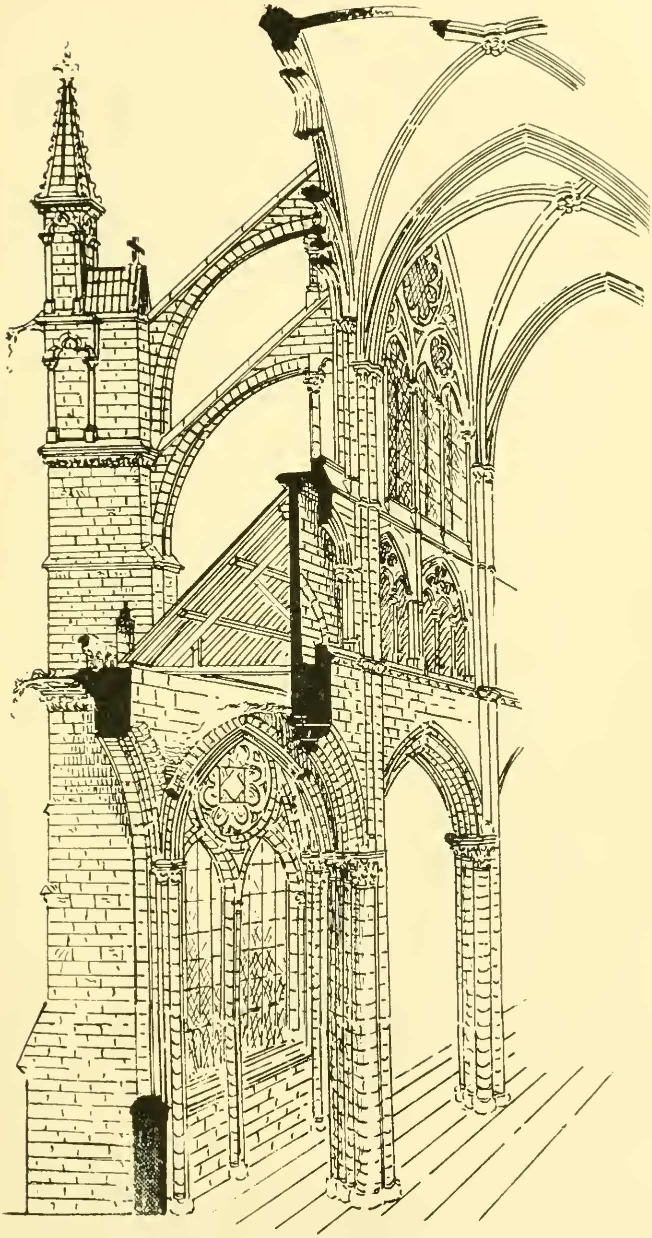


FIG. 7. GOTHIC.

rior semicircular vaultings increased rapidly, and the skill and ingenuity of the builders were taxed severely to meet them.

Other difficulties arose in using the round arch with churches having different widths of nave and transepts and still different lateral openings. The arches could not be brought to a uniform height, the intersecting lines were awkward and the general effect often unpleasant.

In the early part of the twelfth century, while the builders of the mediæval churches were struggling with the difficult problems presented, a happy solution was evolved in the pointed arch. See Fig. 7. The many advantages of this form of arch soon became apparent, and the round arch, with all its sacred traditions and venerable service, was abandoned at once; for this new and advanced step in evolution was a necessity, reducing the thrust of the vaulting about one-half and allowing arches of many different spans to be brought to a uniform height with graceful intersections and secure construction.

The pointed arch not only solved the mechanical difficulties of this church-building age, but lent itself so naturally to the upward tendency that a new impetus was given, and churches and cathedrals, designed and commenced in the Romanesque style, were often carried up in the Gothic style to a much greater height than the original designers had dreamed of.

The intelligent application of the pointed arch to interior groined vaulting soon brought about the complete system of Gothic architecture, in which the entire load and active thrust of the vaulting are concentrated at individual points, and the weight is transmitted to the ground by slender piers, while the outward thrust is met by flying buttresses reaching over the roofs of the aisles. These flying buttresses, instead of springing from thick and massive walls, rest against deep buttresses which may be considered as so many sections of the old Romanesque walls, placed at right angles to the building line.

In this ingenious and scientific manner the thrust of the lofty vaultings is conveyed to the ground without obstructing the light required for the building, and at the same time it produces a charming effect.

The stone pinnacles crowning these buttresses were erected, not to give variety to the outline, or simply to send up so many aspiring points, but for the more prosaic purpose of lending their weight to secure equilibrium for buttress and flying arch.

The roofs of towers, which at first were of flat pyramidal form, became elongated to the tall and graceful spires of later

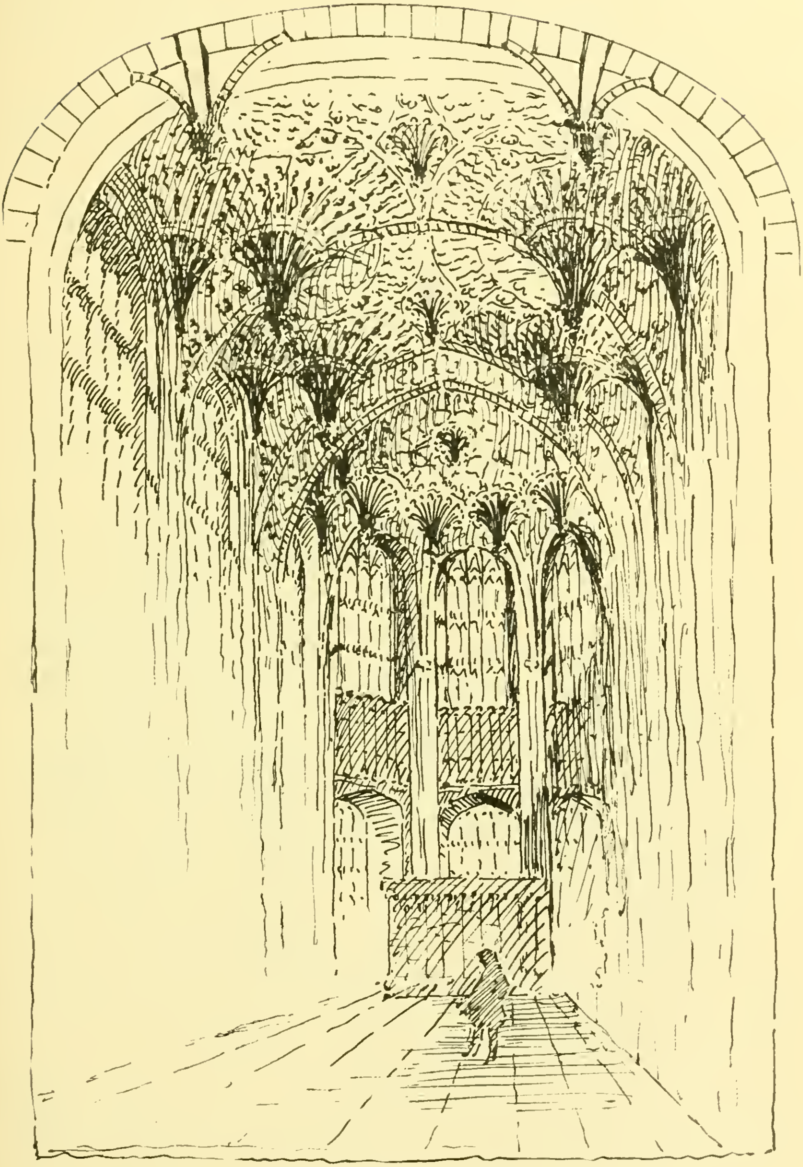


FIG. 8. FAN TRACERY.

days, exerting less thrust on the tower walls than the earlier forms.

In the absence of overhanging cornices to shelter the walls, projecting gargoyles were placed at intervals to discharge the rain water away from the walls; and their usual grotesque features suggest the unpleasant work required of them.

In this manner we may find that every portion and detail of a Gothic cathedral has its special duty, and, in performing it, gives shape and character to the style.

As Longfellow again very truly says:

> "Nothing useless is, or low,
> Each thing for its place is best;
> And what seems but idle show
> Strengthens and supports the rest."

I have said that imagination runs riot in ascribing the pointed arch to other than mechanical origin.

The most common delusion is the often expressed idea that the intricate vaulting of Gothic work was the result of efforts to imitate the interlacing branches of forest trees.

To disprove this, it is necessary only to observe that it was not until the third and last century of Gothic work that the vaultings arrived at any such intricacy, and the steps were very gradual from the plainest possible arched surfaces of the twelfth to the elaborate fan tracery of the fifteenth century, when the builders attempted, by ingenious devices, to conceal the real and true construction.

Another very plausible suggestion of the origin of the pointed arch is that such a form was produced by the intersection of interlacing semicircular arches, as was often practiced for wall decoration in Norman architecture in England.

This indeed might have suggested the *form* to those who were seeking new forms.

But there was no desire to change from the round arch, made almost sacred by its long-continued use and its religious associations. And again, the pointed arch was first employed purely for structural purposes, and in France, not in England.

Other writers, including no less an authority than Sir Christopher Wren, attribute the introduction of the pointed arch throughout Europe to the returning crusaders, who, Sir Christopher says, may have seen it used in Saracenic architecture.

In answer to this, it may be said it is very doubtful, and certainly not proven, that the pointed arch was used by the Saracens earlier than in Europe, while we do know that the round horseshoe arch was then, as now, the common type.

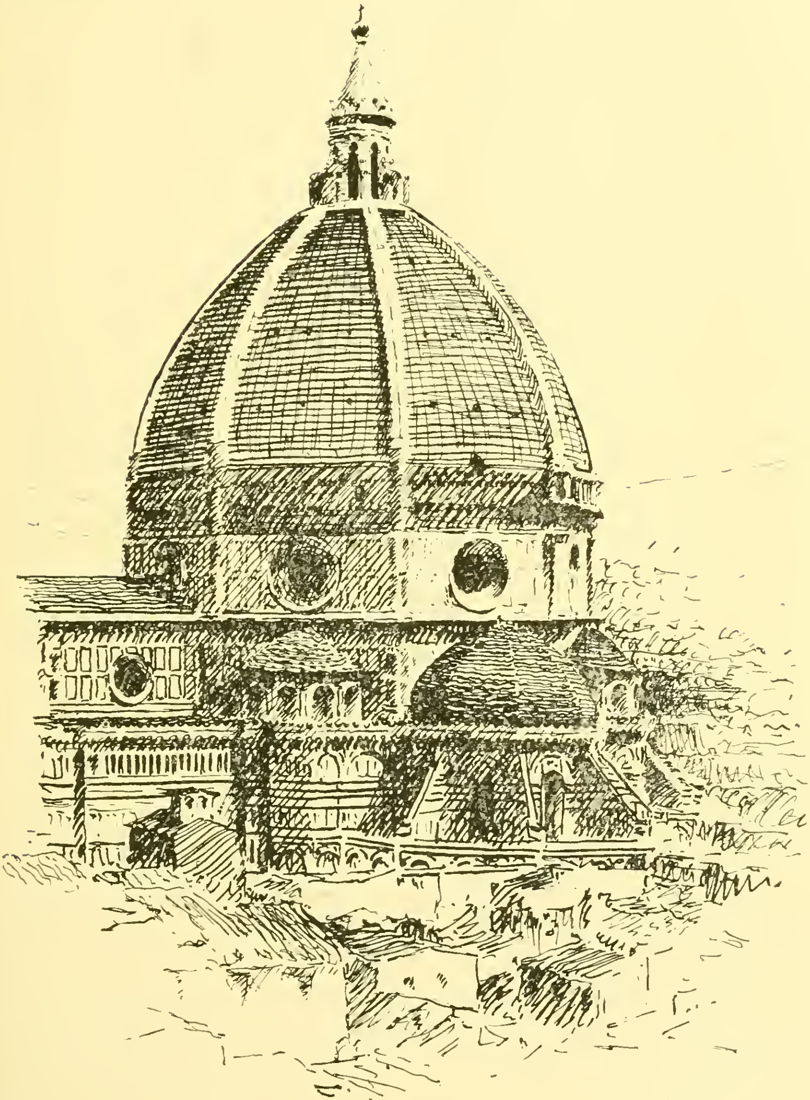


FIG. 9. DUOMO AT FLORENCE.

And, as the returning crusaders did not introduce the horse-shoe arch or any other device or ornament from the East, it is hardly possible that the pointed arch came from that source.

Others, again, have thought the lines of the pointed arch were suggested by the outline of a fish's head, because the fish forms a prominent feature in early Christian symbols.

And still others, thinking such an important feature could not have been suggested by anything "in the earth or in the waters under the earth," attribute it to Divine inspiration.

It was, in fact, such inspiration as in our day put eyes in the points of needles, and gimlet points on the ends of screws,—the inspiration we call invention, the child of necessity.

When the builders of these Gothic monuments had become so familiar with the solutions of their mechanical problems, and had expressed in stone all the structural truths they were conscious of, the spirit of adventure and novelty led them to take liberties with their materials and to produce such astonishing and indefensible features as hanging pendants and intricate fan tracery in their stone vaultings. See Fig. 8. Thus did Gothic architecture ripen and fall, and in its place no new forms arose. The attention of architects was turned toward Rome, and the illogical combinations of arch and classic orders was born again to rule the building world.

I said no new forms arose. It may properly be claimed that the lofty dome, with its lantern or cupola, which forms so conspicuous a feature of the Renaissance, and which crowns its proudest monuments, such as St. Peter's at Rome, St. Paul's at London, the French Pantheon and the Invalides at Paris, is an architectural form new to the world.

We have noticed the dome of the Pantheon at Rome, 143 feet in diameter and built about the beginning of the Christian era, also the dome of Santa Sophia, 104 feet in diameter and commenced about 527 A.D. Both of these celebrated examples were flat domes without crowning lanterns.

The first indication we have of the revival of Roman architecture is in the famous work of Brunelleschi in erecting the dome and lantern on the cathedral at Florence early in the fifteenth century. Fig 9.

This building, designed by Arnolfo, and built up to the vaultings of the nave in the Florentine Gothic style, had remained nearly a century unfinished.

The original design and model (if any were made) for covering the great central octagon, 137 feet in diameter, were lost and forgotten.

Many architects and experts were consulted, and a great variety of schemes advanced and debated.

Most of the plans contemplated a central pier or group of piers to support the roof.

FIG. 10. EIFFEL TOWER, PARIS.

When Brunelleschi, who had diligently studied the Pantheon and other works of ancient Rome, proposed his bold scheme of carrying the walls of the octagon still higher and covering it with a double shell dome, without the aid of centering or temporary supports, he was denounced on every hand as crazy, and his scheme was condemned as wholly impracticable.

After some years of discussion and agitation, he was permitted to undertake the work, which he executed with great zeal, good management and final success, although death overtook him before the lantern crowning the dome was finished. This dome at Florence furnished the model for Michael Angelo at St. Peter's, and for all modern domes in masonry.

While the Renaissance has been practiced with many variations in the civilized world for the last four hundred years, we look in vain for new architectural forms. We find only new combinations of old forms, and the question is often asked, will a radically new style ever be invented?

If my argument is correct, that the architectural styles of the past have been developed by applying the best mechanical knowledge and skill to the materials at hand in solving the structural problems presented, then it follows that new styles may be expected only with the advent of new materials, or of new structural problems to be solved. In our own day we have both of these conditions presented in certain directions, and we shall see how new architectural forms are being developed.

The new material presented to the builders of our day is metal. It is only about fifty years since iron was first considered a possible material for architectural forms.

At first it was cast in the well-known shapes of columns, arches and entablatures, and set up as hollow shams, painted and sanded to look like stone. This was not good art or good mechanical application, and therefore it could not produce a living style.

Iron and steel, however, were constantly demonstrating their worth under the hands of skillful engineers, and the proper forms for utilizing their good qualities were found to be with the wrought metal rolled into bars, rods, flanged beams, angles, etc., and put together with bolts and rivets. With this material, the mechanical engineers have solved the problem of spanning rivers and chasms that would be impossible with stone; as, for instance, some of the bold bridges across the Mississippi, the graceful suspension bridge between New York and Brooklyn, and the stupendous cantilever bridge over the Firth of Forth in Scotland, with its two spans of 1700 feet each and trusses over 300 feet high. The Eiffel Tower in Paris (Fig. 10), 1000 feet high, gives us, indeed, new architecture, but a form that will meet only a few limited conditions.

Similar applications of iron or steel to the problems of the day have given us the great clear spans of our central railroad stations, and of large buildings as in the roofed court of the Manu-

factures Building at the Columbian Exposition at Chicago, where the clear span was 380 feet and the height over 220 feet.

This naked condition of beams, bars and rods, as applied to roofs, bridges and lofty towers, is not adapted to the general problems of domestic, commercial or monumental buildings, except as an auxiliary, and in the requirements of the modern office building it is an important one.

The prime object of the modern office building is to earn the greatest possible return for its owners. This means that it must present the greatest rentable space possible on the lot, with every part well lighted and ventilated, easy of access to all parts, fire-

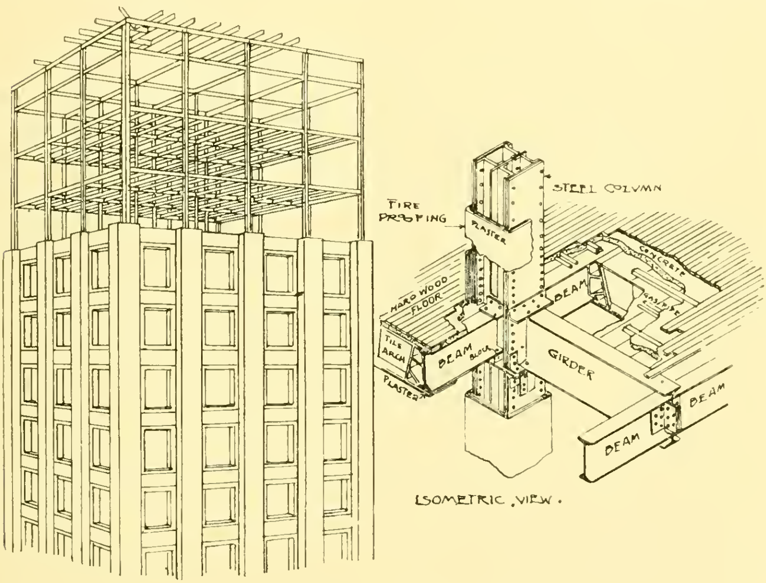


FIG. 11. MODERN OFFICE BUILDING.

proof and secure in its construction, with every modern convenience for its occupants, and with a good degree of elegance presented to those who enter it. See Fig. 11.

The attainment of this prime object has been greatly enhanced by the very modern steel skeleton construction, making buildings twenty stories high as safe and practicable as those of five stories by the old method, while the rapid-running elevators, in sufficient numbers, make the top stories as accessible as was the fourth or fifth under the old method.

Here we recognize the conditions possible for a new style, and the first important steps have been taken in some of the modern

sky-scrapers, by ignoring all historic styles, and developing the simplest possible form, as in Fig. 11, by clothing the skeleton frame with the necessary flesh and skin of brick and terra-cotta. But, as this covering skin is the old historic material, it is hardly probable that the detail or ornament applied will differ much from that with which we have been made familiar, and it remains to be seen what this age of metal will develop.

As we commenced with a style worked out in bamboo, we end with a style being developed in steel, and we may feel assured that, as every historic style has been the result of continuous application of correct principles applied to the materials and conditions imposed, modern science will work out as satisfactory solutions of its problems.

DISCUSSION.

Mr. Schulze.—In the development of style the matter of environment is a very significant factor. I believe it is Ruskin who calls attention to the sky-line of Southern States, and compares it with the sky-line of Northern States. That thought occurred to me as Mr. Percy was showing us the drawing of that Grecian temple in the south of Italy. There were the long horizontal lines perfectly in tune and touch with nature in that country. Then, as we go north, we see the Gothic cathedral, which has an upward tendency of all the lines. Ruskin calls attention to the sky-line in the Northern States in connection with the cathedral.

I believe it is an admitted fact that environment, and particularly natural environment, has had as much to do with the development of ordinary style as the particular needs of the people with whom those styles originated.

In regard to the Leaning Tower of Pisa, I am inclined to differ with Mr. Percy in his assertion that it is the result of accident, or due to defect in construction. I have not all the facts in my mind now, but at one time I looked into the matter quite thoroughly, and, from the evidence and from the discussions that I read, everything tended to show that it was not the result of accident, but of deliberation.

Mr. Manson.—Can Mr. Percy tell us the origin of the onion-shaped dome that we see so much in Russian and Turkish pictures? It exists to a large extent in Russian cities, and particularly Moscow.

Mr. Percy.—I do not know the origin of that.

Mr. Wagoner.—What did the architect rely upon to relieve the thrust of the dome in Florence?

Mr. Percy.—Aside from the thickness of the walls, which is

about 15 feet, there are two hoops or bands. The two hoops are made of timber, with iron straps at the angles. The dome is not circular, but octagonal in plan. All the other modern domes, or nearly all (such as St. Peter's, which was the first great dome after Florence), are circular. In St. Peter's the iron hoops were put around the inner dome at the time it was built, and others have since been put around the outer dome. This was done because there was some danger of its spreading. Some of the iron bands have been broken. The thrust of these domes is comparatively small. The construction is such as to reduce the thrust to the lowest possible amount. The shell is made as light as was in those days considered prudent, although I have no doubt that in our day we would not use more than half the amount of masonry. The inner wall is about 5 feet thick. The architect, in building the dome, employed methods that made it possible to build it without any centering to support it while being built. Of course it is evident to every one that a horizontal ring, once completed, would support itself. It was built so that the courses of the joints were all vertical. In the lower portion there were long and short stones used, and, when a ring was completed, every alternate stone stood up half its length above the others. After that long stones of the same length were used, and they remained in place because the center ot gravity was supported. You will understand that every course presented the appearance of a beveled tooth-gear wheel, and in that way the dome was carried to completion without centering.

Mr. Schulze.—A rather interesting story occurs to my mind in connection with that dome at Florence. An artist living there, by the name of Ghiberti, afterwards became famous for the gates that he designed for this same building. He was not an architect. The dome was not completed, and, from what I can gather, the architect, Brunelleschi, enjoyed less of the confidence of the people than did Ghiberti. The result was that they were both appointed to complete the dome. In the course of their joint labors jealousies arose. Brunelleschi soon discovered that Ghiberti was utterly incapable of carrying on the work, and yet he was getting more than his share of the credit. This irritated Brunelleschi to such an extent that he wanted to get out of that rather awkward partnership. He felt that he deserved to have all of the credit. But the difficulty was, how to get out of it. One morning he feigned sickness, and the result was that Ghiberti had to take charge ot the work. The progress was very slow that day. Brunelleschi continued to feign sickness, and the citizens of Florence soon dis-

covered that Ghiberti was not the man for that position, and Brunelleschi was appointed to continue the work alone.

Mr. Percy.—I remember reading that story, and, if I remember correctly, this occurred at the critical time of constructing the timber hoop that I mentioned. Ghiberti did not know how to go to work at it, and Brunelleschi continued his pretended sickness until it was discovered that Ghiberti had no ability for carrying on the work, and then Brunelleschi was relieved of the unpleasant partnership. Up to that time each had equal salaries and equal credit.

Mr. Henny.—You have referred to Chinese architecture as dealing with bamboo structures. Are there any other buildings besides bamboo? Are there stone or brick buildings?

Mr. Percy.—There are stone buildings. The Japanese and the Chinese do not differ much from other nations, so far as I can see. It is the peculiar forms that I selected for my paper—the curved roof and light bracket construction, as shown in their pagodas, houses and other works of that kind—which give the peculiarities to Chinese and Japanese forms. Their mason work is substantial, and they use the stone quite naturally. Where they have basaltic rock, they usually build it up much the same as other people do, and where they have stratified material they build it in courses, the same as others do. All people have taken the most practical way. The stratified material is laid up in courses, and the basaltic material, broken into many-sided forms, is laid up accordingly. In the paper my idea was to bring out the striking forms or outlines, or that which gives character to architecture. I was in hopes there would be a more lively discussion in the direction that Mr. Schulze pointed out. I know that many writers attribute all those things to the natural surroundings and environment, and to other influences of that character. I question this in my paper. Take the illustration that Mr. Schulze presented of the flat Italian styles as compared with the great pointed roofs of more northern Europe. Italy is more like California than any other section of Europe. I have traveled through the great valley of the Po. There the mountains rise on each side, very similar to our own San Joaquin Valley, only the mountains are not so large as the Sierra Nevadas on one side and the Coast Range on the other. It is the great central valley of Italy. Amid such surroundings there is that flat style of Italian architecture, while in Central France, where Gothic architecture developed first and where it attained its greatest perfection, you cannot see a mountain, you do not see sharp peaks. Take the Cologne Cathedral;

you may photograph it on all sides and no mountains will be shown. So with all those great cathedrals, with their tall spires, in Central France there are no mountains to be seen, while there is hardly a city in Italy from which distant mountains are not visible. In Florence and in many Italian cities you can go upon high hills and look down upon the city.

So I do not think that environment has very much to do with the architectural forms. They have developed along the lines that I have pointed out in the paper. I must therefore disagree with Ruskin, for whose opinion I once had very much more respect than I have now.

As to the Leaning Tower of Pisa and other leaning towers, I have read various arguments about them, and especially those of Mr. Wm. H. Goodyear. He has made a most remarkable investigation of the irregularities in Italian buildings, and in many striking cases he attributes it to some deep-laid scheme to produce optical effects. He has shown great ingenuity in making his claims. When I visited the Leaning Tower of Pisa it seemed to me that I could tell from the inside of the building why it was in that condition, from ordinary, natural causes. There were cracks in the walls, and every indication that the building had settled in a way that threw it out of plumb. The cracks are just where you would expect to find them in a building that had settled and was in the position of this tower.

The architects in this country find that it is not an easy thing to build campaniles and lofty towers on soft ground and have them stand vertical. The campanile of the "New Old South Church" in Boston leans a foot or more, but the architects did not intend it should. These lofty campaniles in Italy are nearly always built on alluvial soil, and apparently without finding a good, solid bottom. The Leaning Tower of Pisa is built on soft ground. I have the authority of a French architect, who claims to have dug down and investigated the foundation, that he found it built on piles. To build a lofty, cylindrical monument, and have it stand vertical as against any pressure and various disturbing causes, is much more difficult than the erection of buildings that have a broad base. In nearly all the Italian cities the lofty campaniles are out of plumb. There are other leaning towers besides that of Pisa. There is one at Bologna that is not more than two-thirds as high and which leans over ten feet.

The articles that have been published by Mr. Goodyear in our journals are very interesting reading indeed, and one must admire his ingenuity, however much they may differ from him in his con-

clusions. In nearly every case he attributes the irregularities to some desire on the part of the builder to produce some pleasing illusion, and he often gives some very plausible reasons for it; but the reasons are not always the same—that is, the irregularities may be in one case directly contrary to the one in the other, and yet a similar effect is sought, in his estimation.

Mr. Wagoner.—What influence, if any, upon architecture, did the invention of window glass have? That is, did it modify the style in any manner?

Mr. Percy.—There is no doubt that glass has had its effect, but, in the first place, the date of the invention of window glass is hard to fix. Fragments of window glass have been found (and I have seen this myself) in the ruins of Pompeii. Glass was used to some extent in the time of Christ, but it was not common. The great development of glass, and of windows glazed with glass, came with Gothic architecture. It can now be very readily seen that Gothic architecture is planned to allow enormous windows. At first plain glass was used. The use of colored glass naturally shut off a great deal of the light, and therefore, to get sufficient light with stained windows, it was necessary to make them as large as practicable.

We may be sure that in northern latitudes, before the use of window glass, the window openings were small, on account of the cold, but were larger in southern latitudes, where it was warmer. With the invention of glass it was very natural that the window openings would become much larger. In the period of Gothic church building this was carried to the greatest extent, and painting the glass became an ornamental feature. Before that, in the Romanesque period, the walls were decorated with paintings, but in Gothic architecture there were no walls to decorate, and the decoration was put into the windows. In one case, the great wall surface was painted; in the other, the great window surface was decorated.

STREET RAILWAY TRACK CONSTRUCTION.

By M. D. Burke, Member of the Engineers' Club of Cincinnati.

[Read before the Club, February 16, 1899.*]

The title selected for this paper was requested before the paper was written, and was made sufficiently broad to include anything pertaining to street car tracks. But the writer wishes to announce at the outset that the essay will not be an exhaustive one upon so broad a subject, and will treat upon but two or three features pertaining to such work, the only excuse for selecting such a title being that those features are of rather a general nature. No mention will be made of the topics which have been so frequently and ably described heretofore.

In treating the subject, it appears to be desirable to describe briefly what was done in the days of the horse car, the transition to that which is now being done to provide tracks for the motors at present in use, and, finally, to suggest such forms of construction as would appear appropriate for the conditions which exist, or are likely to prevail in the near future.

More than twenty-seven years ago the writer was employed to reconstruct certain portions of track in Cincinnati, and to replace some curves that were in unsatisfactory condition. He found that the curved rails were iron castings, and that the curved tracks had been constructed as shown by Fig. 1. Only the inside rail was provided with a guard, which was unnecessarily high, the groove was excessively wide, while the outer rail was merely a flat casting upon which the wheel was carried upon its flange. It was thought possible to better some of these conditions, so new patterns were made, and the curved tracks were built as shown by Fig. 2. It will be observed that the "knees," or castings which were intended to hold the timbers to gauge were omitted, and the tie rod introduced, and that both rails were grooved. Prior to that time, these little cast brackets, fastened to the ties with three-inch spikes, had been the sole dependence for holding the track to gauge, and, since the loads were always carried upon the upper outer corners of the timbers, there was always a tendency to widen the gauge. The tie rod was introduced to resist this pressure, and "knees" were afterwards used only where required for straightening crooked stringers, or where joints needed a special support.

*Manuscript received March 18, 1899.—Secretary, Ass'n of Eng. Socs.

This was the first track which the writer ever saw made of grooved rails. This form of rail, somewhat lighter in section, was, at about that time, or soon after, patented, made of rolled steel, bent to the desired radius, and, for many years, was manufactured and sold by the William Wharton, Jr., Company, Limited, of Philadelphia, as the Wharton Patent Curve. The form of rail head has

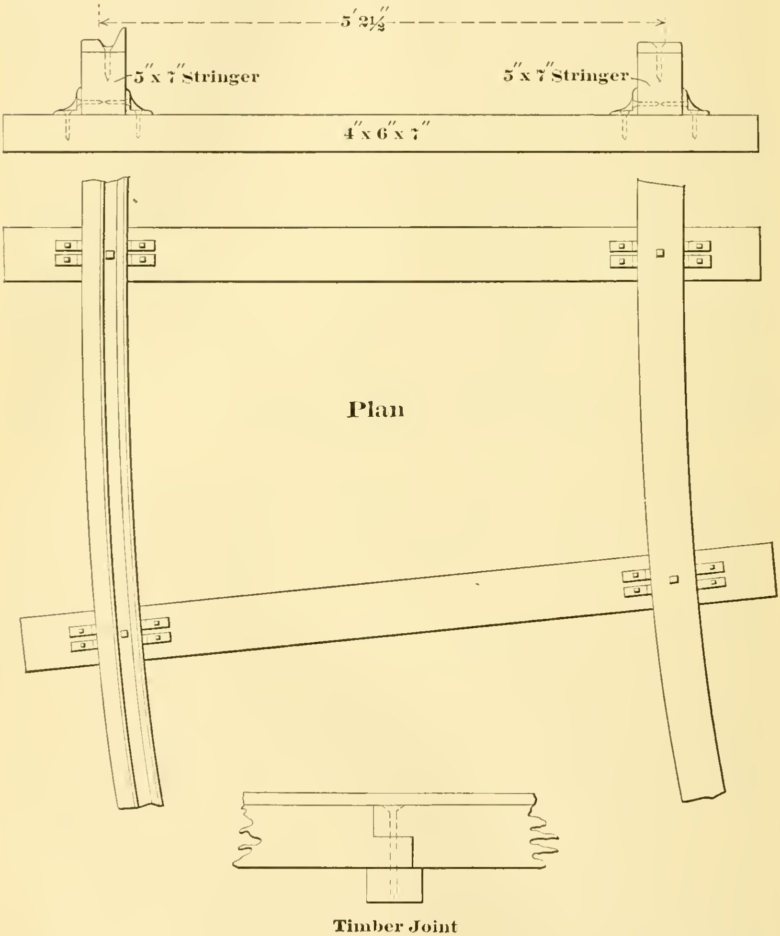


Fig. 1. Plan and Section of Curved Track as Built Prior to 1871.

not been essentially changed in the standard grooved rails of to-day, but the support is different.

In those days street railroad rails were essentially "strap rails," varying in weight from about 18 pounds to 50 pounds per yard. They were spiked to the tops of wooden stringers, which were in turn, fastened to cross-ties, generally with boat spikes, but some-

times with treenails or wooden pins. The earth or gravel was tamped under both the longitudinal stringers and the ties, which were placed four or five feet apart, so that the loads carried, at the speeds then attained, were fairly well supported, while the track was in good condition. But there was an abundance of elasticity, and the "wave motion" that theoretically precedes the locomotive, was generally visible to the naked eye. Each car was usually provided with a "frog," by the use of which the driver was ex-

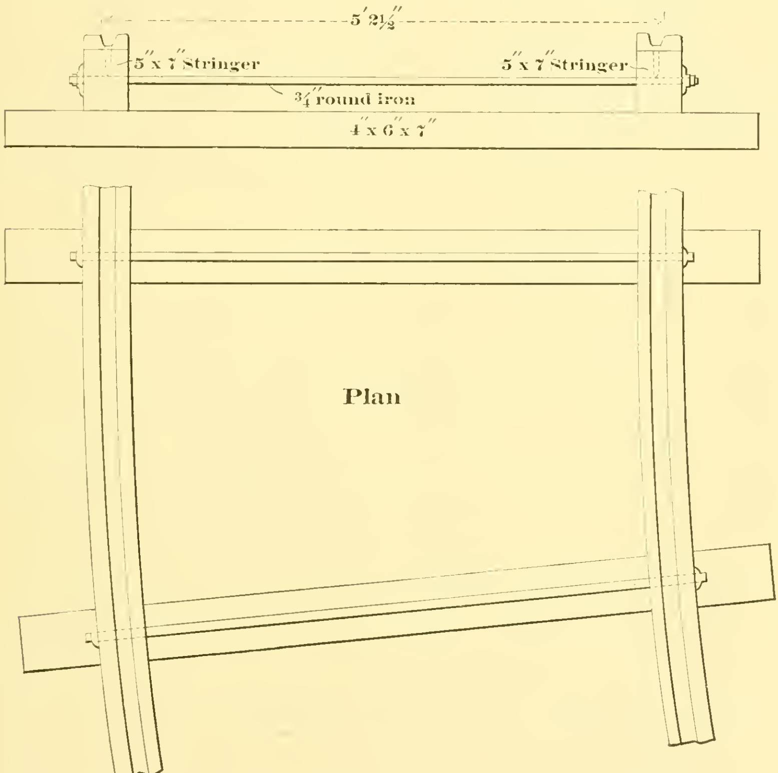


Fig. 2. Plan and Section of Curved Track Built in 1873.

pected to be able to pull his car onto the track, if it got off, or to pull it off and on again, if it became necessary to pass around some immovable obstacle on the track.

The municipal statesmen of those days, in protecting the rights of their constituents, found it necessary to provide a broad inside tram, so that the street car track became a tramway for the use of all vehicles that could travel upon it. The width of the express wagon, to the outside of wheel treads, was found to be about five feet two inches, so the gauge of street car tracks was generally

fixed at five feet two and a half inches, and ordinances provided that the rails should have an inside tram of three inches. As a natural result, vehicular traffic was concentrated along the lines of street railroad tracks, and where double tracks existed was systematized by them to some extent, but vehicles going in the same direction did not travel at the same speed, and the pulling into and out from the tramways was destructive to pavements and tracks as well as to vehicles.

The rails were secured to the stringers by spikes having countersunk heads, driven through the tram of the rails into the wooden stringers, but the expansion and contraction of the rails, due to changes in temperature, either sheared the spike heads, enlarged the spike holes, or bruised away the wood, and the fastening became defective, but the rails were provided with lips coming down over the corners of the stringers which aided greatly in keeping them in place.

Pavements were generally of cobblestone, or the roads were made of broken stone or gravel. Between rails, where the car horses or mules traveled, the most satisfactory roadway was the cobblestone pavement. An eminent engineer of this city invented, and, I think, patented, the pavement made of round locust blocks paved on end. One of our prominent street railroad officials declared that the said engineer made that pavement all out of his own head, and had blocks left. In the tracks it was an utter abomination, as the heart of the locust block polished and became worn to a rounded point, while the residue of the stick disappeared, and animals' feet were destroyed in traveling on the slippery pegs. Where the wooden block is of about uniform density, as cedar, oak, or pine, it does fairly well; but if the traffic is confined to the narrow paths defined for street car horses, it soon becomes worn and does not furnish as reliable and durable footing as the much-abused cobblestone.

A few forms of rails that were used are shown in Fig. 3. "A" shows the "crescent rail," which was laid on Elm street. It weighed about 18 pounds per yard, was spiked, or rather nailed to 3 x 6-inch stringers, had no inside tram, and was rather justly criticised. "B" shows the Route 9 rail, which was laid on Vine street. It weighed about 30 pounds per yard, the rail head being rolled thin to fit over an oak strip, nailed to the top of the stringer. It had the required inside tram, and, if it did not fill all of the requirements, it rattled around in them effectually. "C" was the Mount Auburn, or Route 8 rail, laid on Main street. It was laid on 6 x 8-inch timbers placed flat. It made a very good tramway,

but a rather indifferent car track. There was but little rail head, and what there was rested upon the extreme outside of a broad timber, and was so soon pressed out of gauge that the cars traveled upon the wheel flanges. "D" was used upon the same route, on the upper end of Main street. It was laid on 4 x 6-inch timbers, set on edge. There was much criticism because of the narrow inside tram, but the track, being held to gauge by tie rods, was a fairly good one for street cars.

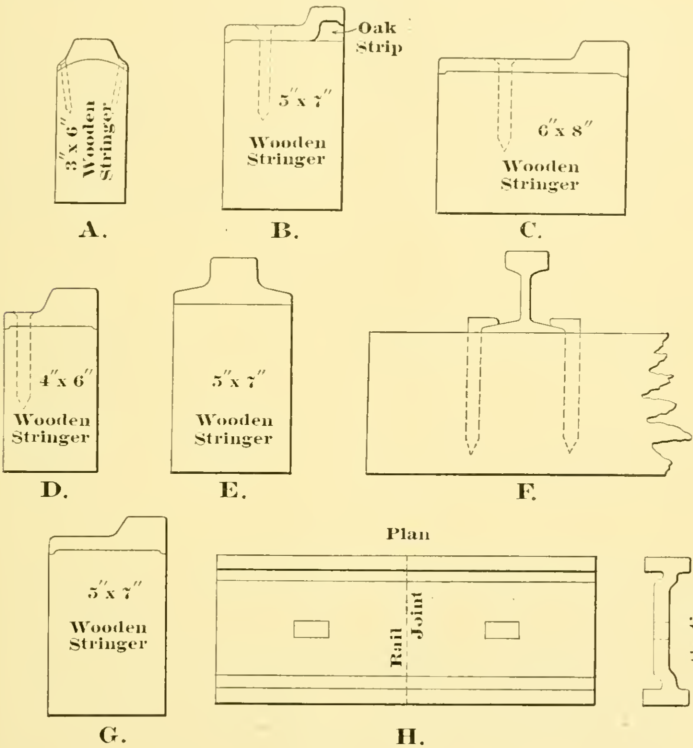


FIG. 3.

"E" is the center bearing or "saddlebags" rail, laid on the eastern part of Route 5, and on Route 7. It was the best of the strap rails, because it had sufficient weight to make it tolerably rigid, and, as it brought the weight upon the center of the timber, it avoided the tendency to tilt the stick over, and thus widen the gauge, as did all of the forms having the inside tram. The lack of the tram brought upon it much censure from teamsters, but it was retained until the advent of the electric motor.

"F" is the standard "T" rail of about 35 to 40 pounds per

yard, always preferred by railroad companies, and very much used, but objected to in pavements, because it provided no tram, but did provide a groove alongside of it in the road. Its defects, from the side of the railroad company, were lack of depth, lack of protection to wheel flanges, and weak joints; while, on the side of the public, it was claimed that no street surface could be maintained adjacent to it.

"G" is the standard tram rail, weighing from 42 to 50 pounds per yard, used upon what was regarded as first-class lines in cities requiring good service and well-maintained streets.

Where the rails met upon the timbers, the wood soon yielded, and the maintenance of the joints became troublesome. In original construction an iron plate about $4 \times 6 \times \frac{1}{4}$ inches thick was used, but it was soon shown that something more rigid was necessary. The cast iron joint plate, shown in plan and section at "H," Fig. 3, was devised by the writer, and was the most satisfactory that he has seen, excepting a plate slightly lighter, but very similar in section, made of rolled iron.

The gauge having been arbitrarily fixed at a width that suited street traffic, it became necessary to construct cars having a short wheel base in order to operate them on the curves necessary to turn the corners in city streets. A rigid wheel base of about six feet was commonly adopted, and we could swing around a circle having a radius of 33 feet to the center of the track. As might be expected, there was some friction connected with such proceedings, but these short curves never occurred upon heavy gradients, and the resistance due to curvature was not the most serious obstacle to be surmounted.

For the empty horse car, the load upon each wheel was about half a ton, seldom exceeding 1200 pounds. The *live* load was exceedingly variable, and generally, good-natured and accommodating. If it found itself off the track, and stuck in a chuck hole, it would often get off and assist in putting the dead load back upon the track. Of average passengers, it takes between fifty and sixty to make a load of four tons, but that load was often exceeded on crowded cars, making the weight on each wheel frequently greater than one and a half tons. These heavy loads, on the yielding timbers, disturbed the pavements, and made street and track repairs continuously expensive. City officers learned that the maintenance of streets carrying car tracks was more expensive than that of other streets, and they began to lay additional burdens on the street car companies. Promoters, failing to realize the great expense incident to street maintenance, frequently accepted grants

which involved such great expense for paving and maintenance, that the conditions of the grants could hardly be complied with. The stringers required such frequent renewals, and the rails were so constantly loose and out of gauge, that some remedy must be devised.

Mr. Johnson had invented an automatic switch, so planned that the mule should turn it by stepping on the proper side of a tilting plate, and thus avoid interrupting the driver when engaged in his legitimate occupation of beating his team. In the few nights that the writer spent with the inventor in this city, setting two or three of those contrivances, Mr. Johnson saw the decayed timbers, and, bringing his inventive mind to bear, he produced the "girder rail." The iron or steel stem and base of the "T" rail were placed beneath the head and tram of the strap rail, the base and stem taking the place of the wooden stringer. Being about right, it soon became popular, and the worst evil now connected with it

A. B.

FIG. 4.

arises from the fact that there are too many forms of it. If standard weights and heights were rolled, the cost of manufacture could be reduced, and better results would follow.

Street railroad companies had become accustomed to the use of light rail sections, the price per ton for iron rails was then about three times the present price for steel rails, the requirement for the inside tram was being rigidly enforced, and the sections produced were influenced by these conditions, so that all defects were not eliminated. In Fig. 4, "A" is a typical section of light girder rail, weighing about 32 pounds per yard, while "B," would then, (say fifteen years ago), have been regarded as a standard heavy section.

In these sections the lack of strength in the joints is at once apparent, and lack of depth became troublesome so soon as any proper form of street pavement was to be placed along the tracks. They have still another defect which people were slow to learn, and which, in fact, is still a mystery to some people who are strug-

gling with low joints. In the girder, the rail head and tram constitute the upper chord, the base of the rail the lower chord, while the stem makes the connecting web. The distribution of the material is approximately as follows: 66 per cent. in the upper chord, 21 per cent. in the lower chord, and 13 per cent. in the web. This is a bad disposition for a beam or girder, especially when the material in the upper chord is subject to much wider and more sudden variations in temperature, than that in the lower chord. The rail head and tram, being exposed to the direct rays of the sun, become much warmer than the base of the rail, and consequently longer; there is sufficient material in the base to cause the rail to curve vertically, loosening it from the ties, and no fish plate or other fastening, and no trackmen, however skillful, can keep up the joints. This condition, with its consequent troubles, still exists with the forms of rails having the inside tram.

When cities began laying stone block pavements, and it became apparent that neither broken stone, gravel, nor asphalt, could be maintained where the top of the tie came within three or four inches of the surface, various devices were brought out for lowering the ties. The "clamp chair," which was especially adapted to what is known as the "bulb rail," in which the lower chord of the girder is given a rounded form, the "box joint chair," the "brace joint chair," and numerous "rail clips" and "tie plates" have been devised, and many are still in use; but those girder rails still keep on bowing up in the middle and down at the ends, and they still continue to loosen any and all of those fastenings, and they are not likely to stop, so long as metals continue to expand when heated.

To obviate these difficulties, and to provide for the greater weights and higher speeds of electric motors, deeper girders are being generally adopted, carrying the rail down on a broader base to a heavier tie, placed at a greater depth. Sixty-five and 70 pounds per yard, are now regarded as light rail sections, while 80, 90, 95, and even 100 pounds per yard, are now common weights of rails used in the tracks of electric roads in the streets of our larger cities. But nearly all of them are laid on wooden ties. It is true that the tie is generally imbedded in concrete, or placed upon a foundation of crushed stone compacted by rolling, but the fastening of the rail is to this perishable tie, and it is inaccessible, except by the digging up of costly pavements, and the interruption of congested traffic. The stringer has gone, now why not eliminate the perishing tie. Leave off that silly inside tram, and omit the wooden tie, and you may be able to make your track for electric roads reasonably permanent.

The maintenance of the street railroad track is essentially different from that of the steam railroad track; and in its construction this difference should be fully considered.

The steam railroad track is placed upon a right of way owned and controlled by the company which owns the track. Its construction, its drainage and its maintenance, are all in the hands of its owners, who supply the requisite material, and direct the workmen under skilled supervision. The joints, the drains, the ties, are visible, and are subject to daily inspection. When the requisitions have been made, and the materials and funds supplied, (it may be that these are sometimes administered in homeopathic doses), there is nobody to consult, no traffic to interrupt but that

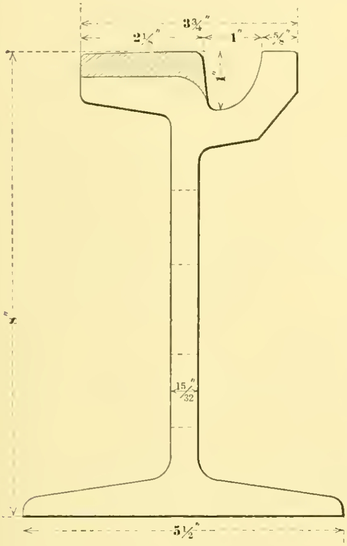


FIG. 5.

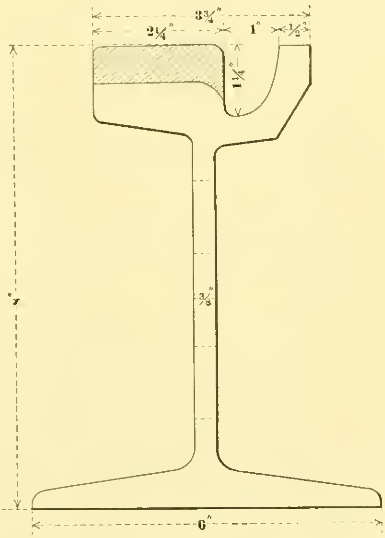


FIG. 6.

controlled by the company itself, and repairs are systematically made, without interference or delay.

With the street car track, these conditions are all reversed. The roads are built in public streets or highways, where everybody has a right of way, and each individual assumes and asserts that he has a little better right than any street car company, when he wants to drive on the street, and an absolute right to be carried on time, when he wants to ride on the cars, he preparing his own schedule.

The track construction is entirely buried from sight, excepting the tops of the rails, and frequently they are covered with

mud. The drainage, when there is any, is under the control of municipal authority, and, unless provided when the tracks were laid, it cannot be either supplied or maintained by the street railroad company, unless it be under conditions which the municipality shall dictate. If bolts or spikes become loosened, or a tie requires better support, such facts cannot be known until a depression is visible in the track, and the adjacent pavement shows the effect of the movement that has been imparted to the rails. Then a permit must be obtained from the authority having control of street repairs, often involving the rights of contractors who have agreed to maintain the pavements, and in due time the street pavement can be taken up, the defect remedied, and the pavement replaced. The delays are so vexatious, and the conditions imposed are so onerous, that what might have been prevented at trifling cost by the tamping of a single tie, or the adjustment of a single joint, has involved numerous delays, and the expenditure of many dollars.

Because these conditions do exist, and for the further reason that street railroad companies should, as a matter of right, use every proper means to render their service as prompt and reliable as it can practically be made, and because the use and occupancy of streets and highways by the street car companies should be attended by the least disturbance of such roadways, and the least amount of interference with their use by the general public, it follows that the construction of street railroad tracks should be of the most durable materials, and the most permanent workmanship that is attainable at reasonable cost. Since the electric motor has taken the place of animal power in propelling cars, and since those cars have been given such weights and speeds that colliding with them is accompanied with great danger, it follows that no tramway should be provided to allure vehicles to their tracks, but that street surfaces should be so formed that wagons will pass over or along the rails without being impeded by the broad groove or rut that invariably accompanies the inside tram. That feature should, therefore, be eliminated from the rail. Where street surfaces are properly paved and maintained, the full grooved rail should be laid. Where they are composed of broken stone or gravel, the deep "T" rail should be laid, having a low inside guard that will provide a space for wheel flanges, and a shoulder against which the road metal can be packed.

Possibly a digression may be permitted for a brief discussion of rail sections. It may be true that some of the sections of girder rails now in the market, have been designed by the men who manufacture and sell steel by the ton, so that weight is fully as desirable

as length of service. Then it may be true that electrical engineers have designed some sections, without having made a careful study of the matter of so disposing the material as to secure the greatest life of rail at the least cost. And then again it is possible that a few city engineers have interjected certain requirements and con-

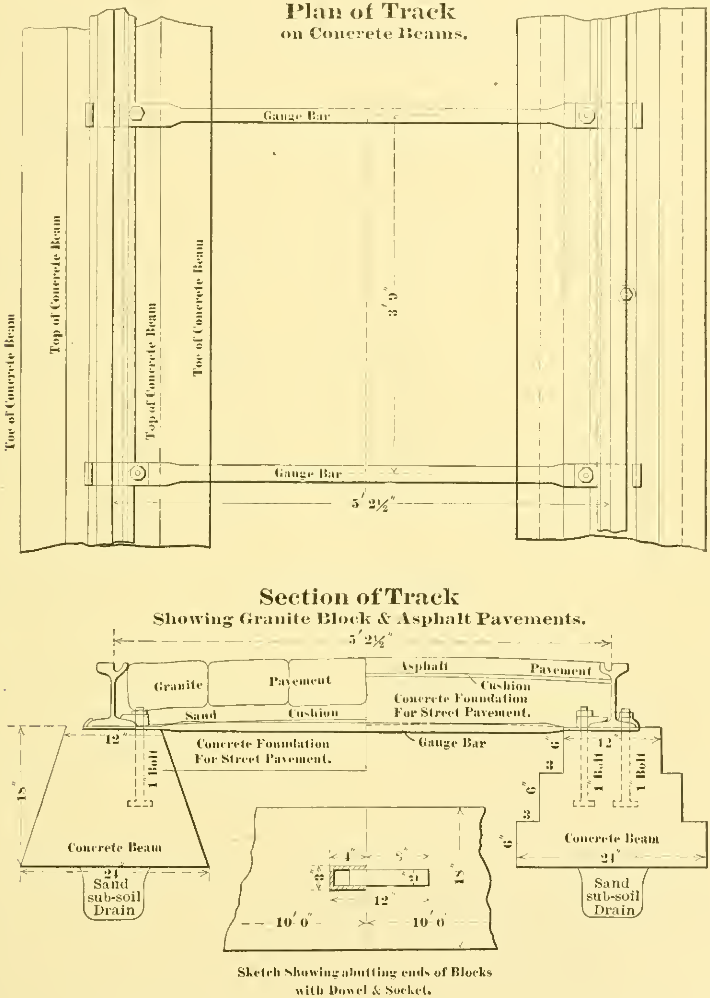


FIG. 7.

ditions, just because they could. At any rate, there is great variety, and many of the sections are not such as can be commended on the score of economy. It is not the purpose of the writer to design a rail, but he is willing to state a few of the principles that, in his judgment, should be considered in making such

a design, and he desires to urge the advisability of adopting standard sections for certain heights and weights, so that the cost of manufacture can be reduced.

In track construction, it may be assumed that the rail is the essential feature, and that it should be so designed that it can be rigidly held in place, that it will resist, without deflecting perceptibly in any direction, the stresses to which it is subjected, and that it will continue to do so until it shall have lost, by actual wear in service, the greatest allowable percentage from that portion with which the wheels come in contact, before it shall be unfitted for service. The rail head upon which the wheels bear, is the only portion subjected to actual wear, and when that shall have lost so much material in service as to cause it to fail to properly support the car wheels, the whole of the residue of the rail becomes scrap. The web and the base serve only to maintain the rail head in proper position. Width of base renders the rail laterally stiff and easy to support. Depth of rail makes it vertically rigid. and carries the rail fastenings down beneath the paving blocks. It also provides space for rigid joint fastenings.

When the rail acts as a girder, the material in the base is subjected to tensile stress, and that in the rail head to compression. To allow for reasonable wear, there should be at least one-third more material in the upper chord, or rail head, than there is in the lower chord or base. In the web there should be sufficient material to transmit the loads to the base. Inasmuch as the web must resist lateral as well as vertical stresses, it is usual to make rather liberal allowances for that purpose, and also to give ample bearing surface for the bolts, but web material, beyond that which is required for these purposes, is wasted, and, adding to the thickness of the web, in high rails, increases the weight more rapidly than increasing any other dimension. It is here that waste occurs. Granite blocks constitute our heaviest pavements. They are 6 inches in depth. There cannot, therefore, be any valid reason for giving rails a greater depth than 8 inches. In a rail having a depth of 8 inches, there can be no possible use for a greater thickness of web than $\frac{3}{8}$ inch. By no calculation or practical experiment can it be shown that a web of that thickness could be deformed by any force, or combination of forces, acting upon it in the track.

As an example, take Section 95, No. 216, as rolled by the Johnson Company, and very extensively used in this city. Fig. 5 shows the rail as used, the shaded portion of the head being that part subject to wear, and Fig. 6 shows a rail of the same weight

and height, just as rigid and strong, the shaded portion of the head again representing the part subject to wear. When that part shall have been worn from either rail, as it will be by continued use, the residue will be scrap. A comparison of the areas of the shaded portions of the sections shows that, if the wear be uniform, the changes suggested would increase the life of the rail about 60 per cent. That is to say, if the rail shown in Fig. 5 has a life of fifteen years, that shown in Fig. 6 will wear, under the same traffic, twenty-four years or more.

The essential differences consist in widening the base, deepening the groove by lowering the guard, squaring up the side of the rail head to lessen the flange friction, and taking material from the web and placing it where it will be subject to wear. But this is only a criticism, not a design. It is made upon a rail section which is very familiar to all of us, and is in fact on a section that is very much superior to many that are in use. The tonnage carried by some of the tracks where this rail is in use closely approximates, if indeed it does not exceed, that upon the main tracks of some first-class steam railroads. That use will wear down those rails, and, unless the joints fail, the wear will be quite uniform, and nearly as indicated upon the sections. It is certainly desirable to defer the day of renewal as long as possible. It is no more difficult to roll one of these forms than the other, and that form should be used which, at equal cost, has the longest life. But it is time to speak of the real subject of the paper, that is, how to lay the rails.

In *Engineering News* for January 5, 1899, are two articles and two designs for "permanent ways" for steam railroads. The one written by a member of the editorial staff of that journal is so readily adaptable to the construction of electric street railway tracks that its author should have full credit for the invention, if there be one. With the modifications which the writer would suggest, to adapt it to street railroad tracks, it is shown in Fig. 7.

The plan consists essentially in placing the rails directly upon continuous concrete beams, placed centrally under each rail, fastening the rails to the concrete by holding-down bolts and rail clips, and holding the rails to gauge by gauge bars. There is nothing perishable in the construction, and, when properly built, there should be no expense for track repairs until the rails wear out. The dimensions of the beams that are necessary, will depend upon the nature of the soil and upon the climate in which the tracks are laid. In the average clay or gravel soils of this vicinity, the dimensions shown on the drawing will be found ample to sustain the heaviest traffic, where the subsoil is properly drained. This

form of construction should not be used upon newly constructed embankments subject to any considerable settlement.

The concrete can be made in its proper position in the street, or the blocks can be made at a factory, hauled to the work and placed in the tracks, being connected by iron dowels, as shown in the sketch. If made in position, the concrete would be placed in three layers, and the sides, instead of being sloping as shown on the left in the drawing, would exhibit offsets, as on the right. The sectional area and the bearing surfaces are the same in either case. The writer, having much more faith in the continuous beam than in either the tamping of the foundation or the dowel joint, would, wherever possible, build the beams in position; but where that process would be impracticable, the other method could be successfully used, and it would have some advantages. For instance, there could be no question about the quality of the concrete, and it could not be used until it had acquired sufficient strength to insure its preservation.

The base of the rail should be about six inches in width, and its depth should be sufficient to give to the rail joints as nearly the sustaining power of the body of the rail as is practicable. If made in position, a bearing plate should be placed under rail joints; if made at the factory, that would not be found practicable. By the plan shown in *Engineering News*, the holding-down bolts are all shown on the inside of the rails, but, for a street car track, the writer would place two bolts in each rail upon the outside, and bring those bolts through the base of the rail, for the reason that the paving may be all taken from one side of a rail, while it remains upon the opposite side, and the pressure might then be so great as to spring the rail inwards, unless the rail clips had very efficient bearings. While such motion would not be likely to be imparted to the rail, the method suggested would certainly prevent it. But there is still another reason,—viz. these two bolts, passing through the base of the rail, would prevent any creeping of the rails; and, as the holes need not be slotted, the expansion and contraction of each rail, whatever that might be, would be confined to that rail length, and its effects could not become cumulative. About one-half the usual allowance for expansion and contraction should be made in track laying, as that would prevent any objectionable openings at the joints, and at the same time avoid subjecting the track fastenings to the extreme stresses brought upon them by attempts to wholly resist such motion.

The quality of the concrete, used in these beams, is an essential feature. Its cost will vary, in different localities, with the cost

of the materials which compose it. In this climate it is not essential that it be made with Portland cement, because it will not be exposed to the direct action of the weather; but, if natural cement be used, it must be of good quality, and the ingredients must be so proportioned and manipulated that the resulting mass will be a dense artificial stone. In this locality, or wherever clean sand, crushed stone or clean gravel is obtainable at the prices prevailing here, it can be made, at a reasonable profit, at $5 per cubic yard. Upon this assumption, let us see what a mile of this kind of construction will cost, omitting the rails and street paving, as those items are common to each kind of track.

Estimated cost of one mile of permanent way for electric street railroad:

1300 cubic yards of excavation at $0.20 per yd	$260.00
120 cubic yards of sand for subsoil drain at $1.00 per yd	120.00
880 cubic yards of concrete at $5.00 per yd	4,400.00
9665 pounds of holding-down bolts, with heads and nuts, at $0.01½ per lb	144.98
32,553 pounds of gauge bars (6′-1″ x 3″ x ⅜″) at $0.012 per lb	390,64
2816 rail clips at $0.04 each	112.64
7089 pounds of joint plates at $0.012 per lb	85.07
Total	$5,513.33

or $1.04 per lineal foot. If the blocks be made in 10-feet sections and connected by dowels, the joint plates should be deducted, and $253.00 added for the cost of dowels and sockets, making the total cost per mile $5681.26, or nearly $1.08 per lineal foot. The cost of the track laying may be assumed to be the same as that for the present form of construction. Since it would necessarily be done simultaneously with the placing of the concrete, the actual expense would probably be somewhat less.

Estimated cost of one mile of street railroad track on ties in concrete:

1400 cubic yards of excavation at $0.20 per yd	$280.00
1175 cubic yards of concrete at $3.00 per yd	3,525.00
2640 ties at $0.45 each	1,188.00
7920 pounds of spikes at $0.0125 per lb	99.00
4693 square yards of rolling at $0.03 per sq. yd	130.79
Total	$5,222.79

or, about $0.99 per lineal foot. If the ties be laid on broken stone, the cost per mile will be about $3850.00, or about $0.73 per lineal foot.

From these figures it will be seen that, if this form of track construction be desirable, its cost is not prohibitive, for in one

case the saving, by methods now in common use, is but 5 cents per foot, or $264.00 per mile, and, in the other, the saving is but 31 cents per foot, or $1636.80 per mile. Now, is it desirable? If it be really permanent, there can be but one answer to the question, and it appears to be perfectly self-evident that a track, properly constructed upon the plan suggested, would cost practically nothing for repairs until the rails should fail from actual wear. Being continuously supported, the rails would not act as girders, but, if the foundation should yield, or be dug from under them, those concrete beams and the rails would carry any electric car now in use over spans of ten or twelve feet without perceptible deflection. The construction does not extend into the ground a sufficient depth to interfere with pipes or other conduits, and at the same time it does rest upon a part of the street that is not likely to be seriously disturbed by the plumber or the street repairer.

The question may be asked, why make the beams so heavy, when the loads upon them are so light? The answer is, that in view of the great amount and unknown position of the excavations that are almost constantly being made in the public streets, it is cheaper to provide a wide margin of safety than to repair the defects that might result from such causes. Then, as we know by recent experience, the frost penetrates to considerable depths in this climate, and would be likely to reach the bases of these beams, but not so as to affect their stability. Were they lighter and shallower, however, its effects might be seriously detrimental to the stability of the track.

The holding-down bolts are spaced 3 feet 9 inches apart, making eight on the inside of each 30-foot rail, and there are two upon the outside of each rail, making ten 1-inch bolts by which each 30-foot rail is secured to its foundation. It is at once evident that this affords far greater security than is now obtained by about three times the number of spikes. The gauge rods are made from flat steel bars 6 feet 1 inch long for our Cincinnati gauge, with rail bases 6 inches wide and $\frac{3}{8}$ inch thick. "The ends are turned up to form claws, which engage the outer edge of the rail flange, and the central part is stamped into a semicircular trough shape, to stiffen it to resist compression. These bars are also punched to slip over the holding-down bolts. It will be seen at once that these gauge bars would offer vastly more resistance to the spreading of the rails than the present spikes in wooden ties. The rails would, in fact, be solidly held to perfect gauge. The

security of this, as compared with the rail braces, tie plates and spikes which are now used, will be apparent."*

Regarding the subsoil drain, which is here shown as filled with coarse sand, the writer believes that to be the most effective material for the purpose, except in rare cases where the inflow of water would be quite considerable, when a tile should be bedded in the sand. It should be connected, by tile drains properly screened, with the sewers or other outlets for the water, at frequent intervals. In placing it in trenches, it should be well compacted, so as to aid in supporting the concrete beams. These trenches should not be filled wlth broken stone, especially in clay soils, as the clay will fill the interstices between the fragments of stone, and the drains will thus become entirely clogged. For the same reason gravel is inferior to sand. Where the subsoil is sand or gravel, the drains will not be required. The quantity of water to be carried by these drains is so small that it will seldom produce a running stream, but it is of the utmost importance that it be cared for, or its effects may be highly detrimental.

For suburban or interurban roads, a lighter form of construction may be used; but, even in such work, the form of track construction herein described would be found economical because of its permanency and the saving that would be effected in track repairs.

As heretofore stated, the writer does not claim much originality for the ideas of track construction advanced in this paper, but he does believe them to be in the nature of real betterments in the work, and therefore worthy of careful study, of elaboration, and, where found to be betterments over present practices, of adoption. The foundation should have the same ownership as the rail which it supports. As little reliance as possible should be placed upon street pavements for the stability of the tracks, and the least possible quantity of detriment to street pavements caused by the presence of the tracks. It is believed that the plan here presented will be conducive to those ends.

---

*From *Engineering News*, January 5, 1899.

THE DEVELOPMENT OF ROADS AND STREET PAVEMENTS.

By Francis W. Blackford, Member of the Montana Society of Engineers.

[Read before the Society, March 11, 1899.*]

Roads which afford easy communication between countries, or different parts of the same country, promote social intercourse among the inhabitants thereof, and add wealth and power to the countries they traverse. These truths seem to have been recognized at an early age, and resulted in the paving of the streets of several of the ancient cities, it is said, as early as 2000 B.C., and from that time down to about the sixth century of this era. Babylon, Nineveh, Memphis, Thebes, Jerusalem, Carthage, Rome and others were paved with large flagstones, and it is said well-constructed highways joined the first four cities mentioned, notably one from Babylon to Memphis.

The first of the ancient roads of which we have exact descriptions were those of the Romans which joined the city of Rome with other cities of Italy, and extended to the remotest parts of the empire, notably into what is now Spain, Germany and France; to the Danube, and finally to Constantinople.

The oldest of all the Roman roads, the best preserved and probably the best known, is the Appian Way, often called the "Queen of Roads." It leads southward from the city of Rome, and was begun in the year 312 B.C.

It seems unlikely that all the Roman roads were constructed in the same manner, but I have been unable to find more than one general description, which is as follows: The first layer was composed of large, flat stones generally laid in mortar; upon this was placed a layer of concrete or rubble masonry of smaller stones, and finally for the top, or wearing surface, a paving of polygonal blocks of from three to six or eight square feet superficial area. These were hard stones jointed with great nicety and imbedded in concrete or mortar, the whole making a total thickness of about three feet; when upon a rock foundation the bottom course was omitted; on the contrary, when the foundation was very poor the thickness of the road was increased. Sometimes the top paving was omitted, and a covering of broken stone or burnt clay or pottery was used instead. The roadway varied from 8 to 20 feet in width, with a footwalk on either side (the roadway of the Appian Way is but 14 feet). They are described as running in a straight

*Manuscript received April 7, 1899.—Secretary, Ass'n of Eng. Socs.

line, regardless of the nature of the country through which they pass. The latter feature would show very poor engineering, and, notwithstanding many statements by modern writers, I am inclined to think that due attention was paid in general to topographical features, and that the mode of construction was changed with the character of the country traversed and the nature of the material available for construction. Most writers have doubtless generalized too freely from facts obtained from an examination of the Appian Way, the line of which is practically straight for a distance of fifteen miles from Rome, and much further for aught I know; but in this distance the country is gently rolling, with no steep slopes. I am also inclined to doubt the statement that the paving was "jointed with great nicety." The poet Horace states that "the roads were less fatiguing to those who traveled slowly." My personal observations sustain this view. The paving of the streets of Pompeii, recently excavated after being covered and unused for eighteen centuries, is unusually rough, and there are many other evidences that the Roman roads, however durable and otherwise excellent, were lacking in smoothness.

With the decline of the Roman Empire and the general disintegration of society in Europe, about the close of the fifth century, the Roman roads fell out of repair and finally into ruin; and, although there was some little paving done in the cities of Paris, London, Florence and elsewhere as early as the thirteenth century, the common roads or highways between cities and throughout the country districts were in a frightful condition until near the close of the eighteenth century. So bad were the roads in England at this time that communication between districts only a few miles apart was practically suspended. Lord Macauley says that "it was no uncommon thing for the fruits of the earth to rot in one place when a score of miles away the people were suffering from a scarcity of the very food which was spoiling almost within their reach."

At this time each parish was obliged to build and maintain the roads within its confines, and oftentimes an impoverished agricultural community was expected to maintain a highway between rich and prosperous towns, a treatment of the subject eminently unwise and unjust.

During the latter part of the period between the decline of the Roman roads and the Renaissance, which began about the same time with Macadam and Telford in England and Tresaguet in France, probably the best roads then in use in the world were those of the Incas in Peru. These were the only roads, with the excep-

tion of those of the Aztecs in Mexico, found upon this continent. Even at the expense of making this paper too long, I cannot refrain from quoting here some passages from Prescott's description of the roads which the Spanish conquerors found there.

"Among them (great works) perhaps the most remarkable were the great roads, the broken remains of which are still in sufficient preservation to attest their former magnificence. There were many of these roads traversing different parts of the kingdom, but the most considerable were the two which extended from Quito to Cuzco, and again diverging from the capital continued in a southerly direction toward Chili.

"One of these roads passed over the Grand Plateau, and the other along the lowlands on the borders of the ocean. The former was much the more difficult achievement, from the character of the country. It was constructed over pathless sierras buried in snow; galleries were cut for leagues through the living rock; rivers were crossed by means of bridges that hung suspended in the air; precipices were scaled by stairways hewn out of the native bed; ravines of hideous depth were filled with solid masonry; in short, all the difficulties that beset a wild and mountainous region, and which might appall the most courageous engineer of modern times, were encountered and successfully overcome. The length of the road, of which scattered fragments only remain, is variously estimated at from 1500 to 2000 miles. Its breadth scarcely exceeded 20 feet. It was built of heavy flags of freestone, and, in some parts at least, was covered with a bituminous cement which time has made harder than the stone itself."

"The other great road of the Incas lay through the level country between the Andes and the ocean. It was constructed in a different manner, as demanded by the nature of the ground, which was for the most part low and much of it sandy. The causeway was raised on a high embankment of earth, and defended on either side by a parapet or wall of clay; and trees and odoriferous shrubs were planted along the margin, regaling the sense of the traveler with their perfumes and refreshing him by their shades, so grateful under the burning sky of the tropics."

These roads were used by footmen and four-footed animals only. No vehicles passed over them.

Just prior to the time of Telford and Macadam, England somewhat improved her highways by the establishment of a comprehensive system of post roads, but the construction was so imperfect that they were not much better than the old roads; and but little permanent improvement was observed until the advent of the two

men named, to whom the people of Great Britain are greatly indebted for the permanent and admirable system of roads everywhere found.

The methods of Telford employed in England and those of Tresaguet in France (the latter being the pioneer by a few years) are much alike, and are briefly described as follows: Upon a well-compacted and well-graded roadbed of natural soil a course of large stones is placed on edge, with the broad side down; these are rammed, and the interstices filled with smaller stones or chippings; upon this foundation is placed by hand and thoroughly compacted a layer of about 4 inches of smaller stones, and finally a covering of 2 inches of finely broken cubical stones, all pieces of which would pass through a ring 2½ inches in diameter. The method of application of the different layers and the details of construction differ slightly, but the result in both cases was a good road; the thickness of which was from 12 to 14 inches, with a crown of about 4 inches. Telford made the crown with the bottom course of stone, while Tresaguet made it in the grading.

Macadam omitted the use of large stones for the foundation, claiming that they were not only useless but injurious; and placed the finely broken stone directly upon the natural soil foundation to a depth of 12 inches. He used stone broken to pass through a 1½-inch ring. None of these pioneer road builders used a binding material.

Modern macadam and telford roads are constructed in a manner similar to the above, except that the material is spread on in layers, with the addition of sufficient binder of stone clipping or fine gravel or sand to completely fill the void between the larger stones; and the several layers are thoroughly compacted by rolling. The best materials for such roads are basalt, syenite, trap, limestone and quartzose grits; most granites and sandstones are unsuitable, the mica causing them to grind up under traffic.

Such roads need constant care and intelligent supervision, and to save cost, both in construction and maintenance, should be only wide enough to accommodate the traffic. Ordinary country roads, unless near large towns, need not be macadamized wider than 14 feet, or sufficient only for two teams to pass easily. By maintaining a crown perfect drainage, the most important single element in road construction, will be obtained, provided the gradient of the road is sufficient to carry the water along after it reaches the ditches. The minimum grade adopted by the French engineers is eight-tenths of one per cent., and in level countries this is obtained artificially by introducing gradual undulations in the grading.

The gradient, up or down, upon which a horse can trot with ease is from $3\frac{1}{2}$ to 4 per cent.; this, therefore, should be the maximum gradient, so that the lighter traffic can go quickly. If the ascent, as in a mountainous country, cannot be made with such a gradient it would doubtless be found economical to introduce stretches considerably steeper, but not too steep to be overcome by the heavier loaded vehicles; under such an arrangement the lighter vehicles could make better time than if the gradient were continuous at a rate too steep to trot upon, and the heavily laden traffic by making a little additional effort could get over the steep places; the adjustment of gradients, however, would depend largely upon the traffic expected.

Such roads as I have just described were built throughout France with great rapidity by Napoleon for military purposes, and all of Western Europe and Great Britain is now traversed by a system of well-built and well-kept roads, the best being those of France and Switzerland.

While there are some fairly good macadamized roads in this country, there are many more very poor ones, notwithstanding the vast sums annually expended upon their construction and repair.

Our roads have usually been constructed by local authorities untrained and unqualified for such undertakings. After the road is once built it receives no systematic supervision or care in its maintenance, an occasional load of gravel put on under the direction of the local supervisor being the extent of the attention bestowed. It is usually built too wide. From lack of care, the crown wears away in a few years, resulting in several parallel ruts, which are always partly filled either with dust or water, to be churned deeper and deeper by each passing vehicle until the road becomes concave and holds water even after the surrounding country has dried up. These defects of both construction and maintenance could doubtless be corrected by a systematic state supervision, and the application of scientific methods. It is my view that their supervision, both in construction and maintenance, should be by a state officer, and that a small tax should be levied and expended for maintenance under his direction, instead of a labor tax, as is now the universal custom.

The only instance of national road building undertaken by our Government was that of the national road which was started about the year 1840, and designed to run from tidewater to the Mississippi River. It was actually constructed from Cumberland, Md., to near the eastern boundary line of Indiana, with a branch, I believe, to Cincinnati. It was a creditable engineering work, and

would doubtless have been greatly extended but for the advent of the railroad, which afforded a better and quicker means of communication. It is about 30 feet wide and substantially constructed. The streams are spanned by wide bridges of latticed trusses on good masonry, almost all of which are still in use. It has long since been surrendered by the National Government to the States through which it passes, and although a toll road at the time I saw it the surface had been sadly neglected, and was concave and worn into several lines of ruts, which, as Horace said about the Roman road, "made traveling less fatiguing to those who went slowly."

STREET PAVEMENTS.

The first modern street pavements were mostly cobblestone, which was composed of boulders that had been worn smooth by the action of water and found either on the banks of streams or in gravel banks. The stones were usually from 4 to 8 inches long, and were imbedded in a foundation of about a foot of sand or fine gravel and rammed firmly to place; when finished the surface of the pavement was covered with from 2 to 3 inches of gravel and sand, which was worked into the interstices by the traffic. This kind of pavement was laid in Boston about the middle of the seventeenth century, and in Philadelphia fifty or sixty years later; subsequently much of it was laid in New York and Brooklyn, and still later in Cincinnati, St. Louis and other Western cities. It became the standard pavement for most American cities up to about 1850, and much of it is still in use.

This form of paving was succeeded by Belgium block, first laid in Brussels and later in Paris and the United States. It consists of rectangular blocks of stone from 6 to 10 inches wide, from 10 to 20 inches in length and about 9 inches deep, laid upon sand and gravel, with sand filling for the joints. After a little wear this makes an abominable pavement, very little, if any, improvement on the cobblestones. The large blocks wear in every direction toward the joints, leaving a series of boulders more or less convex, according to the amount of service received, and being exceedingly rough and noisy, and correspondingly severe on vehicles, horses and the nerves of the inhabitants. Neither pavement has any merit but durability, and is practically obsolete.

There seems to have been but little substantial improvement in American city pavements until about the year 1870, when asphalt and wood came into use both in Europe and America, and soon after, when a better grade of stone blocks were laid. About fifteen years ago the use of brick began mostly in the cities between

the Alleghenies and the Missouri River, and larger areas have since been laid with more or less satisfactory results.

Asphalt pavements are composed either of natural rock asphalt or refined asphaltum, mixed with residuum oil, sand and carbonate of lime. Most of the asphalt pavements of the United States consist of artificial asphaltic cements, made from asphalt brought from the island of Trinidad, or the mainland of South America near said island. The material from the several localities produces about the same result when properly manipulated. When freshly dug the crude pitch is saturated with water, cuts with a knife, like cheese, and is of a brown color; as it dries the color becomes a bluish black, and the bitumen becomes harder. The product, after refining, which is done with great care by a system of indirect heating, contains about 56 per cent. bitumen and 44 per cent. of earthy and vegetable matter. The refined product is put in barrels and transported to the place where it is to be used. It is then melted in kettles, and from 15 to 20 per cent., by weight, of petroleum residue added thereto. From 12 to 15 parts of this material, added to from 83 to 70 parts of sand, and 5 to 15 parts of pulverized carbonate of lime, form the wearing surface of the usual asphalt pavement.

The Barber Asphalt Company's first-class pavement—that designed for the heaviest traffic—consists of a foundation of 5 inches of hydraulic cement concrete, 1½ inches of bituminous binder and 2 inches of wearing surface.

The second-class pavement—that designed for semi-business or residence streets—consists of 4 inches of hydraulic cement concrete, 1 inch of bituminous binder and 1½ inches of wearing surface.

Asphaltum was used by the Egyptians and Arabians for cistern linings and similar purposes more than two thousand years B.C., and is used with success at the present time for reservoir linings; but not until about the year 1838 was it used for street paving, and it did not come into general use until about 1870.

It requires more careful manipulation and more skill in handling to produce a perfect pavement with the artificial, or prepared, product than with the natural bituminous limestones of Europe, or the bituminous sandstones found in California, Utah and elsewhere in the United States; this doubtless accounts for the many failures of such pavements soon after their introduction in this country. Experience, however, in the preparation of the material and the laying of the wearing surface has corrected most of the defects observed in the earlier pavements, and the results now obtained is nearly an ideal pavement. It is the easiest of all pavements to keep

clean, and produces neither dust nor mud. It offers the least resistance to traffic, and with reasonable care lasts from fifteen to twenty years; it is the least noisy of any excepting wood, and although very slippery under certain conditions of dampness, when either wet or dry, it is not objectionable for that reason if laid upon a grade of less than about 4 per cent. Notwithstanding popular opinions to the contrary, it is my belief that a first-class asphalt pavement similar to that just described will withstand successfully the heaviest city traffic, and that it is the most economical pavement now in use (when we consider the wear and tear on vehicles and horses) for the busiest streets of our large cities.

It costs in New York city about $3 per square yard with fifteen years' guarantee; prices elsewhere have fallen to near $2.25, and for second-grade pavement in many instances to about $1.60. It may be said that the prevailing price now is about $2. These prices usually carry with them a guarantee of from five to ten years, and a certain sum for repairs for a period thereafter. The granite block pavements now so generally used both here and in Europe are some little improvement upon the Belgium block which they succeeded, but on the whole they have little merit other than durability and that of affording a good footing for horses on grades too steep for other kinds of pavements. After becoming a little worn they are very slippery, either wet or dry; they are destructive alike to vehicles and horses, and under heavy traffic produce a noise distracting to those unused to it. It is claimed by many physicians that the continuous noise and clatter of the stone pavements is not only trying on the nerves of delicate people, but actually drives many persons to insanity.

Such pavements are expensive to clean, difficult to thoroughly clean, and are usually left badly cleaned, and therefore unsanitary, because of the accumulations of filth in the joints. Granite blocks are very durable, and seldom any part is wasted. Such pavements last from six to forty years, according to the location and traffic. On busy streets the blocks are taken up and turned over, or redressed, after a certain amount of wear; and after becoming entirely unfit for use they are crushed up to make concrete for other pavements, and thereby made to serve some useful purpose to the end.

The blocks are usually from $3\frac{1}{2}$ to 5 inches wide, from 8 to 14 inches long and about 7 inches deep, and should be dressed rectangular and free from projections which make a joint between the blocks greater than $\frac{3}{4}$ of an inch. The smaller the block the better the pavement, for when they are worn in every direction, from the middle toward the joint, they become so many boulders,

and the smaller the boulder the smoother the surface of the pavement.

Most stone pavement is laid on a foundation of sand, above old macadam roadways or a roadway compacted by ramming or rolling. The blocks are simply imbedded in the sand and rammed to a firm and even bed, and the joints filled with fine gravel and hot paving cement. The latter is usually a product of coal tar, with sometimes an addition of asphaltum. The paving cement is intended to thoroughly fill the joints and make the pavement impervious to water. To do this requires from 2 to 4 gallons of paving cement for each square yard. This is often improperly done, and I have doubted its efficiency and wondered whether the result justified the additional cost, which is from 20 to 40 cents per square yard.

Such pavements without a concrete foundation are usually so villainously bad that nothing could either make them worse or improve them. Recently it has become more general to place them upon a concrete foundation. This is a great improvement, and justifies care and expense in their laying.

The cost of granite block pavement varies from $2 to $4.50 per square yard, according to the locality, the foundation and the care used in cutting and laying the blocks. Such pavement is, in my humble opinion, fast becoming obsolete and fit only for wharves, the steeper grades and wholesale districts where the streets are used solely for heavy trucking. It is entirely out of place in any of the streets of Chicago, or on Broadway or Fourth or Fifth avenue in New York, or on any busy retail or residence street. Such streets should be paved with asphalt or wood.

Brick pavement is yet in the experimental stage, and this paper is already so long that I shall treat it but briefly.

Its success depends upon the tenacity of the material, its uniformity and the character of the foundation. The foundation, like that for all pavements, should be impervious and unyielding. Often a layer of brick placed upon their sides is used as a foundation for the top course, which is always laid upon the edge with close joints; the usual custom is to fill the joints with a paving cement; sometimes this is omitted, but with what practical results I am unable to say. Much of this pavement has been laid in the Middle West at a small cost, and for ordinary traffic it has given good satisfaction. It has been laid for as little as 70 cents per square yard, and ranges from that up to $2.

I desire to treat wood pavements more at length, because I believe the importance of wood as a paving material is not recog-

nized in this country. Indeed, there seems to be a popular prejudice against it. On the contrary, it is greatly in favor in European cities, where its use is steadily on the increase.

The use of wood as a paving material began in this country about the year 1870, with the Nicholson pavements, which as a rule proved a failure. This was followed by the introduction of the round cedar blocks, which were placed upon a foundation of broken stone, sand or gravel, or upon 2-inch plank.

This class of pavement was extensively used in the Western States, and, being very cheap, many new towns and cities were able to use it at a time when a more expensive pavement was not available because of a lack of funds.

The cost ranges from 70 cents to $1 per square yard. If placed upon a foundation of concrete, which is the latest practice, it is increased to from $1.50 to $2.25 per square yard. A filling of coarse gravel and paving cement for the joints is used in the better grade of pavements, but the additional expense of 15 or 20 cents per yard for the paving cement is hardly justified in the cheaper grades, and is often omitted.

Its life is from seven to eleven years. Although smooth when first laid, after a few years' wear it becomes somewhat rough, because of the more rapid wearing of the sap than the heart of the wood, leaving it a series of round humps.

The Helena wooden pavement, which many members of this Society has seen, is composed of fir blocks 4 inches wide, from 8 to 12 inches long and 6 inches deep, laid upon a broken stone foundation on Main street and upon plank on Grand street. This pavement has been down eight years, and has given satisfaction to the residents of Helena. The joints were filled with a paving cement and fine gravel, and are from $\frac{3}{4}$ to 1 inch in width; the blocks are tightly wedged together, and cannot be removed without considerable labor. The pavement seems to have been well laid, but shows one very serious defect,—that of having the joints too wide. As a result they have worn rounding on top, and it is now rougher than it should be; and rougher than it would have been had the joints been but $\frac{1}{4}$ of an inch in width. A block 3 inches wide would have made a better pavement.

I took up this pavement in a number of places about two years ago for the purpose of inspection, and found a decay at the base of the blocks extending up 2 or 3 inches in all blocks taken from Main street. Those laid upon the plank foundation on Grand street were perfectly sound, although laid at the same time. I think this pavement cost $2.50 per yard.

Such pavements as I have described are noiseless, afford excellent footing for horses and are easily and quickly laid. They have usually been selected, however, because they were cheap in first cost.

European wooden pavements are very different from those usually seen in America, and would not be recognized as wood without close inspection. This is the paving material used on the busiest and most important streets of London, and the busy and fashionable avenues and boulevards of Paris. It is also used in Berlin, but, as that is essentially an asphalt paved city, the use there is less extensive.

The construction there is briefly described as follows: Upon a foundation of 6 inches of concrete a bed of cement mortar less than half an inch in thickness is spread and made very smooth, and parallel with the crown of the finished street. After this has become hard the wooden blocks are placed directly upon it, with joints of about ¼ of an inch. The joints are maintained during the laying by brads driven into the side of the block to a shoulder. The joints are then run full of hydraulic cement grout, or sometimes paving cement for about 2 inches and then the grout. The blocks are sometimes treated chemically to preserve them, but usually they are merely dipped in creosote oil and allowed to dry. Sometimes wood in its natural state is used. The timber is sometimes seasoned, but often only partially so.

The Improved Wood Paving Company, of London, uses partially seasoned timber, and simply dip the blocks.

The blocks are usually of pine, 6 to 10 inches long, 3 inches wide and 6 inches deep. Some hard wood has been used with more or less success. It is more expensive, however, and has proved more slippery than the softer wood. This standard pavement costs in London about $1.80 per square yard, exclusive of foundation. Fine gravel or shingle is scattered upon the finished pavement, and at intervals during its use; this is driven into the wood by the traffic, and is said to make it less slippery. Its life upon the busiest streets is about eight years; on the less important streets from ten to sixteen years.

The following extract from the *Engineering News* of July 14, 1888, may prove interesting in this connection: "Wood pavements have met with greater success in Europe than in America because they are laid upon a foundation of concrete, and receive more attention in the way of maintenance than is given them here. American yellow pine, owing to its hardness and resinous quality, has been the favorite wood in Berlin and Hamburg. A report from Berlin

states that the Frederick Bridge was paved in March, 1879, with yellow pine and is still in good condition, while the approaches, paved with granite block, have since required twice repaving. The Opera Platz in front of the Emperor's palace was paved in 1882 partly with yellow pine and cypress at the point where the traffic was greatest; at the other points stone blocks were used, and were laid at the same time. To-day the area having the wood pavement is the one which is the best preserved."

This pavement affords a good foothold for horses, offers very little resistance to traffic, is the least noisy of all pavements, will stand the heaviest traffic and altogether has so many points of merit as to place it in the very front rank as a paving material. I should place it along with, if not superior to, asphalt for the finest and busiest streets of our large cities, but I do not recommend it as a cheap pavement designed for secondary or resident streets.

It has usually been so considered in this country, and to that, more than any other reason, I attribute the unfavorable opinion generally held concerning it. It was made of cheap, untreated material, carelessly laid upon an inadequate foundation; necessary repairs were entirely neglected, and has by no means had a fair chance, while in Europe it is composed of the best grade of material, generally treated to prevent its absorbing urine and other deleterious matter; placed upon an impervious and unyielding foundation, that requisite for any good pavement, and laid with great care by skilled workmen, and always kept in excellent repair.

It is in no sense a cheap pavement, and should not be so considered.

If there is luxury in street paving, as in almost everything else at this age, I see no reason why wood should not, along with asphalt, come into general use. In most things our comfort, ease and pleasure are important considerations. In the ordinary walks of life a man doesn't dress himself in duck or corduroys, or in any way select his apparel, strictly because of its durability or economy. He selects that which is comfortable, pleasing to the eye and otherwise suitable to his occupation, condition in life and general environments; while, on the other hand, in the majority of instances durability and first cost are the only factors considered in the selection of a paving material. Why the people residing or doing business on our wealthiest streets should submit to a rough and noisy stone pavement, when a first-class wood or asphalt pavement is entirely within their means, has always been a surprise to me; and I cannot but attribute it to lack of knowledge of the results obtained elsewhere, with very little if any more cost.

DISCUSSION.

In the discussion which followed the members generally agreed with Mr. Blackford that properly constructed wooden blocks and asphalt pavings were the best under the most trying conditions.

Mr. C. W. Swearingen, City Engineer of Great Falls, stated that the paving in Great Falls is cedar blocks on 6-inch concrete foundation, 1-inch sand cushion, with filler of gravel and pitch, and 5-inch granite curb. The cost was as follows: Paving $2.50 per square yard; complete curbing $1.25 per linear foot. The paving has been in use three and a half years on the principal street, and so far has proved very satisfactory.

ADDRESS BY JAMES M. PAGE, RETIRING PRESIDENT, BEFORE MONTANA SOCIETY OF ENGINEERS, AT ITS 12th ANNUAL MEETING, IN HELENA, MONTANA, ON JANUARY 14, 1899.*

To the Members of the Montana Society of Engineers:

The Montana Society of Engineers was organized July 5, 1887, with forty-eight charter members. Out of these twenty-one are now active, four honorary and seven associate members of the Society; thirteen of the charter members have withdrawn and we have lost four members by death, two of whom—Benj. H. Greene and Walter W. DeLacy—were occupying the office of President of the Society at the time of their decease.

We have had an addition of twenty-two members during the past year, and we now have honorary members four, active members one hundred and twelve, associate members eighteen, the total being one hundred and thirty-four.

I like the plan adopted by my predecessor in his annual address at Butte, a year ago, in giving a review of the year's engineering progress in our own State, and I am sorry I can only partially follow his example.

NORTHERN PACIFIC RAILROAD.

Charles S. Bihler, engineer of the Western Division of the Northern Pacific Railroad, located at Tacoma, has kindly furnished me with the following very complete information regarding improvements made by the Northern Pacific Railroad in Montana during the past year.

East of Billings.—Revision of grades between Glendive and Montana State line, from 1.25 to 1 per cent. virtual grade.

Revision of grades between Glendive and Billings to an 0.4 per cent. westbound and an 0.25 per cent. eastbound; former gradients 0.5 per cent. each way.

Improvements of line around Big Horn, Myers, and Huntley Bluffs, throwing out 50 per cent. of curvature and getting away from bluffs, in order to insure safety of trains.

New construction, branch from Rockvale to Bridger, 20 miles.

134 pile bridges filled or renewed with steel; 80 miles of track newly ballasted; 20 miles main line 56-pound steel rail replaced by 72-pound steel; new and improved coaling stations at Miles City

*Manuscript received February 17, 1899.—Secretary, Ass'n of Eng. Socs.

and Forsythe; Big Horn Tunnel lined throughout with concrete walls and concrete arch.

West of Billings.—Revision of grades between West End and Bozeman from 2.1 to 1.9 per cent. virtual.

Revision of grade between Bozeman and Logan from 1.0 to 0.8 virtual.

Revision of grades between Garrison and Avon from 1.0 to 0.7 per cent. virtual.

95 miles of track ballasted.

45 miles of 56-pound steel rail replaced by 72-pound steel.

Roundhouse addition, 6-stall, at Livingston.

Car shop addition at Livingston.

Roundhouse addition, 6-stall; boiler house and improved coaling station at Missoula.

Improved coaling stations at Garrison and Jocko.

22-stall roundhouse, boiler house, sand house, oil house and cinder pit under construction at Butte.

Big Boulder bridge at Big Timber replaced with steel structure.

3974 lineal feet bridging filled.

New construction—Branch from Renovo (Parrot) to Twin Bridges, 22.4 miles.

I am indebted to Mr. Eugene Carroll, chief engineer and superintendent of the Butte Water Works, for the following:

"The Butte City Water Company, during the year 1898, has built, above its main reservoir, an additional settling basin of about 70,000,000 gallons capacity, formed by a crib dam 42 feet high by 300 feet long on the crest. This basin was built for the purpose of settling the spring freshets before the water is allowed to enter the main reservoir, and also to give us additional storage during the low water season.

"In the city we have extended our mains about two miles to cover new districts built and improved during the year."

The irrigation scheme in the Jefferson Valley, mentioned in Mr. Goodale's address of last year, was completed this year and used during the month of August. The completed ditch is about 13 miles long, and has a capacity of about 1200 miner's inches. During the present year we kept the ditch only about one-half full, so as to get everything settled and in good shape before testing its full capacity. As far as can be seen at this time, it will be a success and will be used by five different ranches in the valley.

This is all the work which has been done under my supervision during the year 1898, with the exception of the completion

of the cleaning of the bottom of the main reservoir, from which we removed, during 1898, about 20,000 cubic yards, with a view of avoiding the spoiled water with which we have been annually troubled in Butte. The surface earth was removed from the bottom of the reservoir to the depth of at least four feet, so as to remove all vegetable organisms.

MADISON CANON DAM.

Mr. O. B. Suhr, the engineer in charge, whose headquarters are now at Norris, Mont., has kindly furnished me a few notes on this new enterprise, although he says that he can give no definite information as to details, as the plans are yet incomplete. The dam site is located in the Lower Madison Cañon, three miles below Case's ranch, and about eight miles southeast of Norris.

"In a distance of nine miles there is a fall of 276 feet, out of which there is obtained an effective head of 200 feet by means of dam and flume.

"The work is now being prosecuted on a small plant of 501 horse power output, which is designed to furnish the local power market and to supply power for the larger construction, which will have an output of 10,000 horse power to be transmitted to Butte.

"Up to this time the work has been almost entirely preliminary. A wagon road is just completed down the cañon to the dam site, for the small plant; a bridge is in process of construction across the river, and some work has been done on the dam."

From other sources I learn that, to build this dam, a tunnel is run in the overhanging cliff and filled with powder, and, when they are ready for the dam, the fuse will be lighted.

Mr. A. E. Cumming, Engineer and Superintendent of Construction of the Fort Belknap Irrigation System, says that the enterprise is only fairly started.

The proposition is for the Government to provide an irrigation system for the Indians on the Fort Belknap Indian Reservation.

The work is done by the Government for the Indians and paid out of moneys due them for lands sold to the Government under treaties of 1890 and 1896. So far, the Indians have done all the work and are reported by Mr. Cumming as being fairly good workers.

After a careful examination of the water supply available for irrigating purposes on the Reservation, Mr. Cumming reports to the Department that Milk River may be utilized to irrigate the

fine bottom lands lying east of the agency on the Reservation. This and Big Warm Spring Creek are the only streams on the Reservation that can be utilized for a practical system or irrigation.

The water is to be taken from the river by a dam which is to be a "crib 7 to 9 feet high, filled with rock, the crest being about one foot above the bottom of the canal. It will be 8 feet wide on top and 250 feet long, with a triangular section extending up stream, with the top sloping to the bottom at an angle of about 36°. The entire crib is to be covered with 3-inch plank with sheet piling driven well down in the bed of the stream along the entire bottom of the dam to prevent leaking underneath. The water is to be raised 4 feet above the top of the dam by flash-boards, which will be removed during high-water season. This dam will make an available storage supply of from 50,000,000 to 60,000,000 cubic feet, as a lake will be formed 10 to 12 miles long, an average of 200 feet wide and 5 feet deep, in addition to the flowing supply of the river. This will furnish enough water to cover 2000 acres two-thirds of a foot deep. The estimated cost of the dam and head works is $11,535. The water supply from Milk River at its flood stage has a flow of 5500 to 6000 cubic feet per second. There are no official data available of the amount of water flowing in the river during each of five months, beginning with May to September."

It is proposed to utilize the water from Big Warm Spring Creek by building a reservoir which will cover 150 acres, in which the water will be 50 feet deep at the deepest part when full. This reservoir supply, it is expected, will furnish water to irrigate 3000 acres.

The work thus far has been done at a cost of less than 10 cents per cubic yard for excavation.

THE MONTANA POWER COMPANY'S DAM.

The dam across the Big Hole River, near the mouth of Divide Creek, you will remember, was a source of considerable discussion at our last annual meeting. Many of you visited this dam at that time, and hence you are familiar with the plan upon which it is built, and with its topographical surroundings.

It is a timber crib structure, 60 feet in height at the spillway, with a base of 100 feet in width and 500 feet in length.

At the discussion referred to, it appeared to be the opinion of all who had visited it, as well as of the engineer in charge, Mr. M. S. Parker, that the dam, which was nearing completion, was

built on the correct plan, considering the character of the stream, and with all the necessary precautions as to its strength and its durability to resist the pressures that may be brought against it. Mr. Fanning, the consulting engineer (who, I understand, planned the structure), has a world-wide reputation as a hydraulic engineer, and it was believed that he would not be associated with a project which would endanger life and property below it; that the company would not spend half a million dollars in an unsafe structure, and that everything had been done and was being done to insure perfect construction, etc.

Mr. Parker has a very able article in the *Engineering Record* of August 6, last, describing a "partial failure of this dam," from which I quote briefly:

"On April 18, the dam not being fully completed, the maximum flow of the stream for this year was reached, coming fully six weeks earlier than the usual time of high water of the stream. In three days the volume of the water increased from the normal flow of 350 cubic feet per second to ten times that amount, and, notwithstanding that the two sets of waste gates provided were open, one located 50 feet below the crest, with a discharge area of 54 square feet, the other set 20 feet above, with an area of 40 square feet, the water rose to a height of 4 feet over the crest."

This unexpected pressure proved too much for the structure and caused a partial failure, the extent of which will undoubtedly be given you in Mr. Parker's paper on this subject to-day.

I refer to this dam chiefly because the question as to what is the best and safest plan for building dams in our mountain streams is of the most vital importance to the engineering profession in this state. These streams, owing to the rapid melting of snow along the many tributaries early each season, are subject to change in a few hours' time from a gentle flowing stream of a few thousand inches of water to a raging torrent.

RAILROAD CONSTRUCTION.

According to the latest reports at hand, 3018 miles of new railroad have been constructed in the United States during the past year. This is 1138 miles more than in the year 1897, and more than any year since 1892. There are five States in which no new track was laid, three States had only two miles each, and thirteen States over 100 miles each; Nebraska added less than one mile, and Minnesota 250, of which 146 miles were constructed by the Great Northern Railroad.

The retiring Presidents of the Society, for the past two years,

have pointed out that men of engineering skill and experience should be appointed by the Executive to positions where such qualifications would be of decided advantage to the State. It is a question yet to be answered why it is that the State should not have the benefit of the services of men fitted by education, training and experience to fill positions especially connected with the Land Department, where such training and experience are of vital importance in handling and protecting our various land grants.

In conclusion, I congratulate you on the very gratifying increase of membership in the Society during the past year, and upon the prosperous and generally healthy condition of our Society; also on the broad ground of American citizenship.

As a nation we have made history faster during the past year than during any like period since the landing of the "Mayflower." Spain forced upon us the gage of battle, which we accepted with reluctance, but not with fear, knowing full well "that chains are worse than bayonets, even though the chains were on the limbs of others, and the bayonets directed at ourselves."

Spain had the satisfaction of blowing up the "Maine" and killing 266 Americans, and it has cost her 21 warships, two armies and over 160,000 square miles of her territory. A year ago she governed over 10,000,000 people outside of her own limits. Now she governs less than 200,000.

But, after all our grand achievements, both on land and sea, and acquisitions of territory, it is a serious question in the minds of some of our best statesmen whether it would not have been better for us as a nation if Dewey had sailed away after destroying the Spanish fleet in the Manila harbor. A few months since we were not acquainted with ourselves as a nation, but the prestige of our country is greatly increased throughout the world, and our flag has taken on new splendors. I firmly believe that the United States is capable of solving any question and of handling anything that it undertakes.

PARTIAL FAILURE OF THE TIMBER CRIB DAM OF THE MONTANA POWER COMPANY NEAR BUTTE, MONTANA.

By M. S. Parker, Member of the Montana Society of Engineers.

[Read at the 12th annual meeting of the Society on January 14, 1899.*]

The main object of this paper is to call to the attention of engineers some of the elements of failure to be guarded against in the construction of high timber crib dams, and to give the writer's views as to some precautions necessary to be taken to avoid disaster.†

The timber crib dam has for many years been popular in the United States, where economy in first cost has been considered necessary, and it will continue to be popular there. This form of dam, however, is rarely built to a height exceeding 30 feet, although there are no valid reasons why these structures should not be carried up to any desired height when the necessary precautions are taken.

There are instances where the construction of solid masonry dams is beyond the range of possibility, from the standpoint of financial success. The instance herein mentioned is one in point. The site of the dam is in a canyon, well calculated to sustain a timber crib dam. The foundation for the dam is composed of large boulders, fine and coarse gravel, embedded in stiff yellow clay. Above this underlying stratum is loose gravel, sand and boulders. The site of the dam lies between two parallel ledges of rock, one of granite, the other of quartzite. These ledges run at an angle of about 45° with the course of the stream. The bottom of the gorge, through these ledges, is of unknown depth; and the north end of the dam rests in a V-shaped formation in the granite ledge that stands at an angle of about 10° from the perpendicular, forming an excellent anchorage. The south side also has excellent anchorage in the ragged sides of the quartzite ledge. The depth to the solid bed rock, between these parallel ledges at the point of contact, is undetermined, but, from indications, it must be very great. No soundings were made, as it would have involved large expense to determine the depth to bed rock, and the

*Manuscript received March 23, 1899.—Secretary, Ass'n of Eng. Socs.

†Note.—This dam was referred to in C. W. Goodale's Presidential address. See address and views of dam in Vol. XX (1898), No. 5, p. 313; also, Canyon Ferry Dam, referred to by Mr. Parker in same volume and number.

character of the foundation as obtained was considered suitable for the construction of the type of dam to be built.

To obtain a bed-rock foundation for a masonry dam placed the enterprise beyond the reach of financial success. The general plan of the plant of the Montana Power Company is familiar to some of the members of the Montana Society of Engineers, who visited the work during the last annual meeting of the Society, and the President in his annual address gave a general description of the work contemplated.

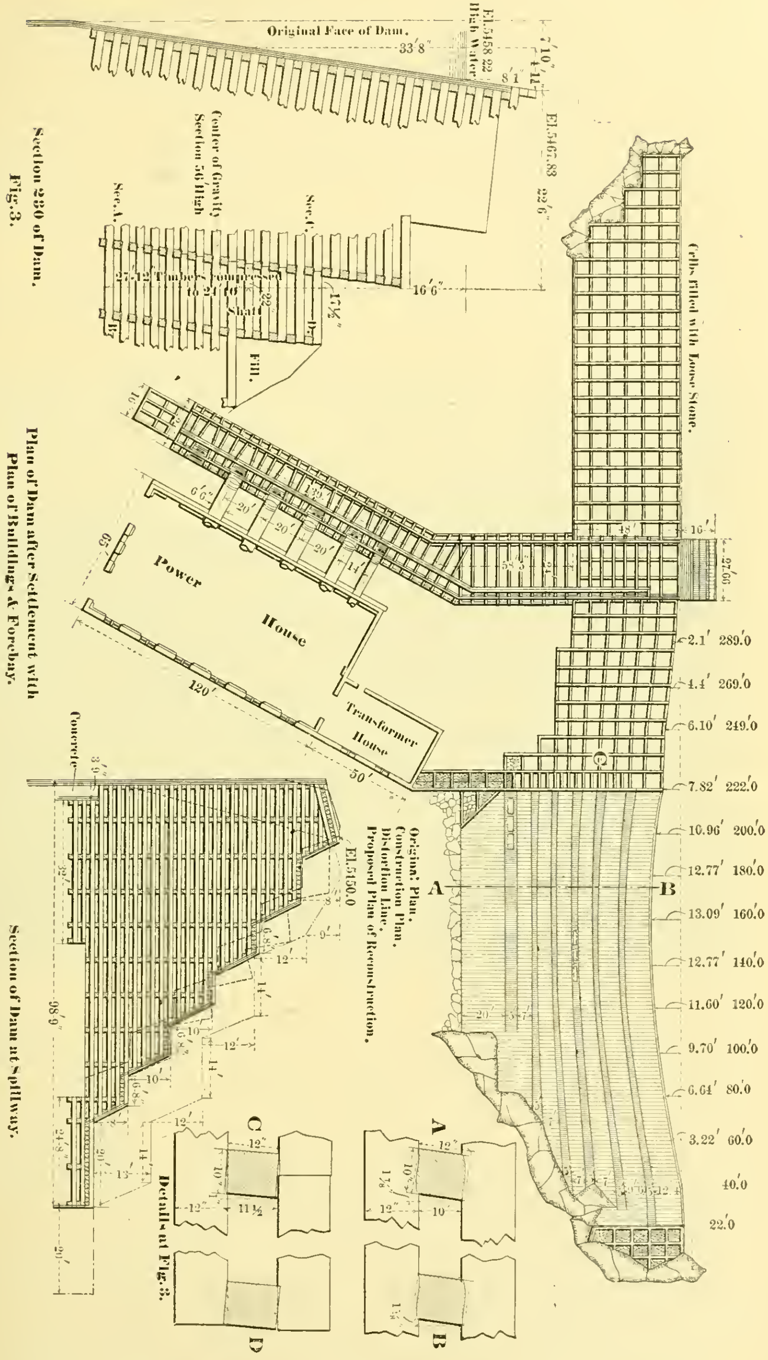
Before entering into the details of the causes of the partial failure of the dam, it may be well to give a general description of the power of the plant of the company, its object, and the conditions governing its inception.

The plant is located on the Big Hole River about three miles from Divide Station on the Oregon Short Line Railway, the object being to generate power and transmit it by electricity to Butte, about twenty miles distant.

The development involves the construction of a dam 60 feet high, to obtain head for the operation of turbine wheels. The water supply thus obtained for the reservoir is to be supplemented by water from two storage reservoirs located about 20 miles above the main reservoir at the plant, on the north and south forks of Wise River, a tributary of the Big Hole River. The reservoir on the north fork has an estimated capacity of one billion cubic feet, while the south fork reservoir is estimated to contain about half this amount.

The combined capacity of the reservoirs would be about 1,500,000,000 cubic feet. This amount of water, utilized for power purposes under the 60-foot head obtainable at the power station, is equivalent to 325 gross horse power per day for one year. Having this amount of water in reserve, it will be readily understood that the normal stage of water in the power reservoir can be maintained, so that the established minimum flow shall not fall below the quantity estimated for power purposes. The average minimum flow of the Big Hole River at the power station was found by the writer, from measurements taken daily from August, 1897, to April, 1898, to be about 350 cubic feet per second.

During this period, while anchor ice was obstructing the flow, the minimum flow would sometimes run as low as 250 cubic feet per second. From intermittent measurements, taken during several previous years, the minimum flow was assumed to be greater than that found by the writer during the time of his measurements. The company had based its investment upon the pre-



DIAGRAMS SHOWING DISTORTION OF THE TIMBER DAM OF THE MONTANA POWER COMPANY.

vious measurements, and had assumed an average minimum flow of not less than 400 cubic feet per second. This amount of water, utilized for power under a 60-foot head, is equivalent to 2720 horse power.

Assuming a 75 per cent. working efficiency for the turbines and a further loss of 10 per cent. in the transmission of electricity to Butte, the works would make a net delivery of 1836 horse power in Butte.

The investment was based upon the commercial value of this amount of power. To maintain this estimate of 400 cubic feet per second was the object of the storage reservoir system mentioned, which had not been contemplated in the original plan of power development. Upon the commercial value of this power delivered in Butte it was estimated that the project would support a capital investment of $500,000. After considering several plans for development, one for the construction of a solid masonry dam 60 feet high, another for building about two miles of large steel conduit in connection with a low dam for acquiring necessary head and volume of water, the form of dam hereinafter described was adopted. The plans formerly proposed placed the cost of development beyond the capital obtainable for the purpose.

These facts are mentioned merely to explain why a rock-filled timber crib dam was built, instead of a solid masonry dam.

A section of the dam at the spillway is shown in Fig. 1. This is constructed of 10 x 12-inch pine and fir timber, laid in cribs with 8 feet between centers. The height of timber is 12 inches and the crib work is filled with broken granite. The fine material is obtained by stripping and quarrying the granite. Openings between the timbers were packed by hand with broken granite of irregular surfaces, while the interior of the cribs was filled in loosely with the above-named material, dumped from cars. (Fig. 4 shows the high section of the dam beyond the spillway section.) The dam has a length of 500 feet with height of 60 feet from low-water mark to crest of spillway. The width of spillway is 200 feet. The rest of the dam is 10 feet higher than the spillway, and the spillway section consists of a series of steps 10 feet high, the tread or apron of each step being 7 feet wide and consisting of two layers of timber each 10 inches thick.

The high section of the dam, Fig. 4, is carried up in 10-feet steps with vertical faces, which are filled to a uniform slope from the original ground surface.

Fig. 5 is a view of the spillway section under construction.

The face of the dam consists of three layers of plank securely spiked to the crib work. The first layer is of 2-inch plank. Over this is a 3-inch plank, breaking joints with the first and secured to the crib timbers with 10-inch boat spikes, two spikes to every face timber. Over this is a third layer of 2-inch plank, also breaking joints. All plank used was surfaced on one side and placed vertical on the face of the dam.

The crest of the spillway, like the aprons above described, is composed of two layers of 10-inch lumber, with the seams calked with oakum. All the timbers, of crib work and aprons, were

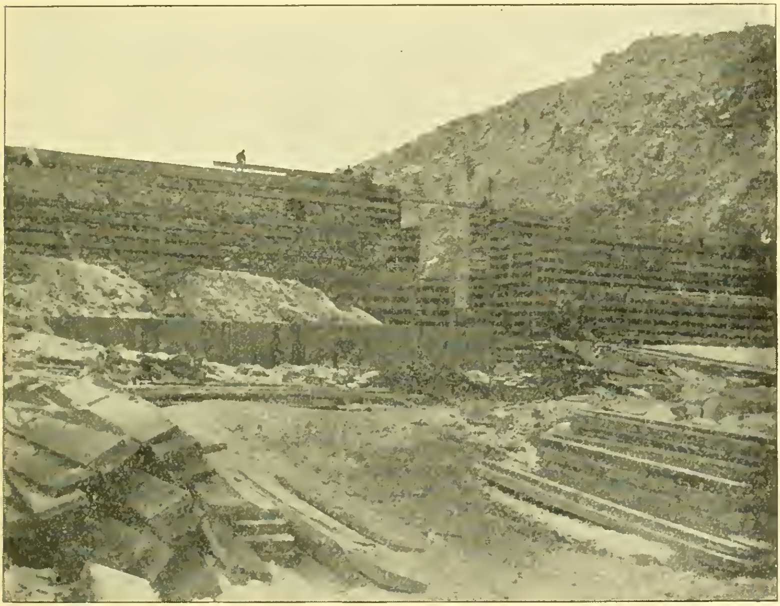


FIG. 4. VIEW FROM BELOW DAM DURING CONSTRUCTION OF HIGH SECTION.

securely bolted with drift bolts $\frac{3}{4}$-inch square, 20 and 28 inches long. Two 28-inch and three 20-inch bolts were used in each 16 feet of timber.

As before mentioned, the bottom of the foundation of the dam is a bed of stiff, yellow clay, with boulders and gravel cemented together. The depth of the foundation, below the original surface of the ground, varies from 12 to 25 feet on the face of the dam. This depth is filled with a strong, concrete core composed of one part Utah Portland cement, two parts clean sharp sand and five parts broken stone. This core is 3 feet 9 inches thick and extends from the foundation to about 6 feet above the original surface of

the ground. It follows the face planking down and is confined at the back by layers of 2-inch plank spiked to the crib work, as shown in Fig. 1. Concrete is also used in front of the face planking for about 10 feet above the foundation. The excavation, made in reaching foundation, is back-filled with it across the river bottom, extending from the north end of the dam for about 300 feet. The remainder of the excavation for foundation, outside of the planking, is filled with a semi-clay puddle rammed in layers to the height of the original surface of the ground. Above this clay puddle and concrete filling, on the up-stream face of the dam, is an embankment of silt, with a slope of 3 feet horizontal to 1 foot in height. This embankment is about 15 feet high above the concrete filling on the face, and about 6 feet high above the clay puddle. The face planking is relied upon to prevent leakage, the granite filling for weight only. Water is taken from the dam, through gates, into a large wooden flume or fore bay, 28 feet in depth and 15 feet in width. The power house is a granite and concrete structure, with a steel truss roof. The building is 120 by 65 feet in plan, with an annex 50 by 30 feet for transformer house. The power house is divided into two bays by an interior row of columns, which support two traveling cranes, each of 7½ tons capacity. It was the intention to supplement the water power with a steam plant. Hence the power house was made much wider than would have been necessary for water wheels and generators alone.

From the fore bay, five steel penstocks lead to five 66-inch turbines of special design. Each turbine is directly connected to a generator, and on the generator shaft is a coupling for engine connection.

The turbines are made by the James Leffel Company, of Springfield, Ohio. When running at 180 revolutions per minute, with a head of 60 feet, they are guaranteed to generate 1200 H. P. Lombard governors are used for regulation, and are guaranteed to regulate the power within 5 per cent. under any conditions. The water that will operate these governors is taken from the fore bay and filtered before it passes into the operating cylinders. The generators, of which four will be installed, are of the 3-phase type and are furnished by the General Electric Company. The generators are of 1000 H. P. capacity each, and of the revolving field type. Current is generated at 800 volts, but is raised to 15,000 volts by the transformers, of which there are 12, of 250 kilowatts capacity. The exciters, two in number, of 100 kilowatts are sufficient to excite five generators. Each exciter is

directly connected to a turbine running at 600 revolutions per minute.

The pole line measures 20.6 miles in length. Poles 30 to 60 feet in height are used, in order to maintain, as nearly as possible, uniformity of grade. Power is to be transmitted by six No. 1 B. & S. copper wires, with an estimated loss of 9 per cent. at maximum load. The poles are set about 50 per mile. Each pole supports three cross-arms, the upper ones $10\frac{1}{2}$ feet and the lower ones 3 feet long. The top of the pole and the ends of the upper cross-arms support glass insulators, to which barbed wire is attached

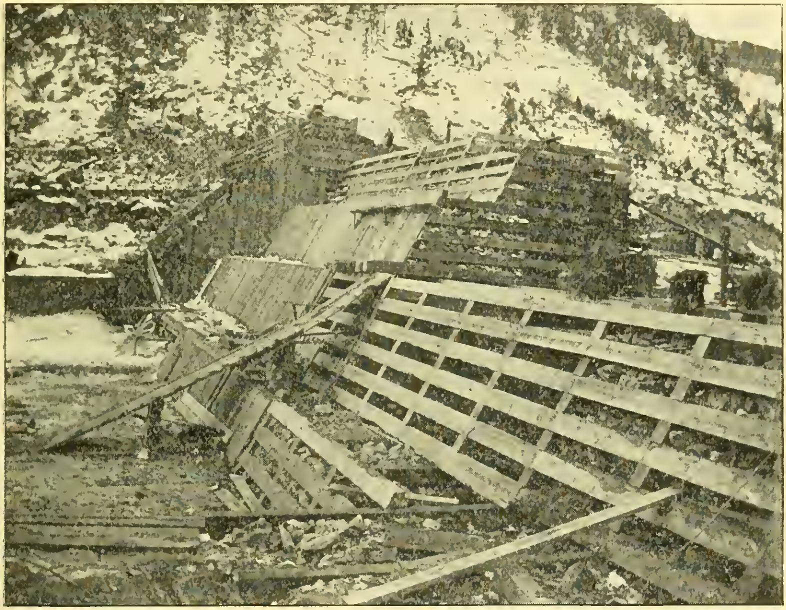


FIG. 5. VIEW FROM BELOW DAM DURING CONSTRUCTION.

as a lightning arrester. The barbed wire is grounded every 500 feet. The middle arm is for power wires, which are supported by porcelain insulators. The lower arm is for telephone wires. The foregoing is a general description of the plant, as designed, without going into details.

Work on the plant was suspended June 1, and the writer severed his connection with the company. He is informed that several changes have been made in the plan as herein outlined. A penstock, 11 feet in diameter, has been substituted for the large wooden flume, as intended in the original plan. The change was made under direction of the president of the company.

A tunnel is to be cut through the ledge on the north side, to be used for a waste way to drain down the pond. The waste way will be regulated by a system of gates, arranged to control the flow. The transformer building is also omitted. Except for these changes, the writer understands that the plant is to be finished as before outlined.

The promoters of the Montana Power Company had the project of the development of this power under consideration for several years, with Mr. J. T. Fanning, a well-known hydraulic engineer, as consulting engineer. Plans were finally matured, and the contract for construction was awarded. The writer was then engaged as engineer in charge of construction, and the active work of construction begun September 1, 1897. The company desired the work pushed to completion at the earliest possible moment, and stipulated in the contract a period of ninety days for its completion. This clause, however, was subsequently stricken out, and a more reasonable one substituted, requiring all possible haste consistent with the employment of sufficient labor and means. Work was carried on throughout the winter months without cessation, few days being too severe for men to work. Under such conditions, work was not only very expensive to the contractors, but in some respects less satisfactory than it would have been under more favorable conditions of temperature.

The excavation under water for foundations was accomplished under great difficulties. Constant annoyance arose from the freezing of steam and water pipes, and from the ever-present ice that formed on everything coming in contact with water. It was only by persistent work and at great loss to the contractors that the dam was finally completed.

About the 10th of April, 1898, the water in the river gave indications of an early rise. Work on the up-stream face of the dam was pushed as rapidly as possible, as well as work absolutely necessary to be done in advance of high water. It was the intention to close the waste discharge gates, of which there were two sets, prior to the period of high water, in order to fill the reservoir slowly, and to allow all settlement of the dam to occur gradually. One set of these waste gates was located at an elevation of 50 feet below the crest of the spillway, the other set 20 feet below. The lower set had an open water area of 60 square feet, while the upper set had a clear area of about 50 square feet.

The openings through the dam, for water to discharge from these waste gates, were sheeted over with two layers of 2-inch plank. The sides and roof of the sluices were of solid 10 x 12-inch

timber, and each waste sluice was divided into three compartments. The plan of gradually filling the reservoir was upset by the early flood that reached its maximum flow on April 18. The water rose so rapidly that in forty-eight hours it attained a depth of several feet above the spillway crest, although the waste gates were all wide open. The estimated flow of the river at this time was 3500 cubic feet per second, or about ten times its normal flow previous to this date. This condition is of unusual occurrence; the period of high water usually occurring early in June. At no time, however, during the following season did the flow exceed that of April 18. During this period of high water the dam was subjected to a severe test, and the result of this test is what the writer desires to call to the attention of engineers.

Fig. 2 is a general plan of the plant, showing the position of the dam after the high water had subsided. The face of the dam

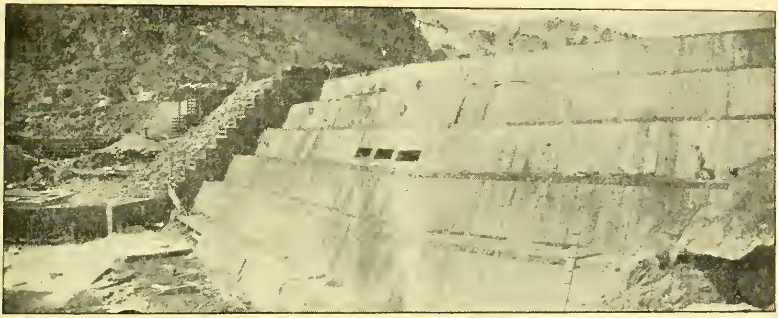


FIG. 6. BIG HOLE DAM. VIEW FROM DOWNSTREAM PREVIOUS TO ACCIDENT.

was built on a straight line; the plan shows the curve given it by the force of the water.

Fig. 1 shows a section of the dam through A-B on the plan, Fig. 2. This figure shows the section as built, the form assumed during high water, also the section as proposed by the writer for the rebuilding.

Investigating to ascertain the causes for this action of the dam under the combined forces acting upon it, two shafts were sunk in the crib work, one at the point marked C on the general plan.

Fig. 3 shows cross-sections of shaft at C. From this investigation it became apparent that the timbers in the crib work had been compressed along the line of pressure. The resultant pressure, from the overthrowing pressure of the water and the weight of the section of the dam, brought undue compression upon the

sections of timber exposed to it. The timbers of the cribs, at their intersections of 8 feet centers, presented a bearing surface of 100 square inches only. The resultant of pressure, at a point 60 feet below the crest of the dam, is 148 tons for one foot of section on the line A-B, Fig. 2. If the line of greatest pressure comes at an intersection of timbers, as above mentioned, and if there is nothing but the timbers to support the load, we have a load of 2960 pounds for each square inch of the surface; and, if we assume that each wall of the 8-foot crib is to carry its full load under the above conditions, we have eight times the above load, or 23,680 pounds per square inch.

The crushing strength of Montana white pine and fir lumber, from tests since obtained by the writer, is about 400 pounds per square inch for pine and 600 pounds per square inch for red fir, for about three per cent. compression of the height of blocks tested, and an ultimate load of about 2000 to 4000 pounds per square inch. (See table of tests appended.)

This result shows the compressive strength of Montana pine to be about one-third that of good, long-leaf yellow pine.

It is not to be supposed, however, that the timbers, at intersections, were intended to carry the loads shown. The cribs, being filled with loose rock and the fine material before mentioned, with the openings between the timbers filled with stone placed by hand to form what is termed a dry wall, was intended to carry the load proportionately with the timber. From observation, however, the writer is convinced that the laying of rock of irregular surfaces, in what is termed a dry wall, between the timbers of crib work, does not give bearing surface sufficient to resist the pressure under the conditions mentioned, no matter how carefully they be laid. Observations in the shafts mentioned show that the irregular surfaces of the rock, placed between the timbers, are pressed into the wood. The section of shaft shown in Fig. 3 contains 27 timbers, each originally 12 inches high, compressed into a distance of 24 feet 10 inches. The total settlement of the dam is 4 feet at the lowest point at the crest along the line of pressure. The settlement or compression, as shown in the shaft mentioned, bears its relative proportion of this 4 feet.

The compression of the timbers, with the settlement of the material in the cribs, occurred during the period of high water, from April 16 to 25. As soon as the water had subsided, alignments and measurements were taken, and subsequent high water caused no further change in the structure. The crest of the dam, as shown in Fig. 2, curved toward the downstream face, the greatest ordi-

nate of curvature being 13 feet inward from the original face line of the dam. The base of the dam remained rigid. The backward movement of the face began at a point about 50 feet below the crest height. The face planking remained rigid, and simply moved backward. The deflection from the original elevation of the face was only that due to the change from the vertical to the backward slope given it.

It is always interesting to an engineer to investigate the causes of certain results. At the instance of the company the plans and workmanship of the structure under discussion were examined by several engineers, who were well able to pass judgment upon both. The question of failure, from compression that actually occurred, was never surmised by any of them. The question of foundation was long under discussion, and great pains were taken to be absolutely sure of its stability and of its water-resisting qualities. A well-known hydraulic engineer, who assisted the writer in making an investigation of the causes of the deflection of the dam, remarked afterward that he would not have thought it possible, had he visited the work previous to the failure. The necessary weight of structure and apparent rigidity of construction were there. The structure was pronounced safe by all. Still it failed in an unforeseen way, that experience teaches can be avoided. The precedent established can be used with profit in future designs of this nature.

The writer has already stated that the compression of the timbers occurred between April 16 and 25. No absolute measurements could be taken prior to the latter date; but from the personal observation of the writer he is convinced that the action took place immediately upon the application of the load. As the water rose toward the crest of the overflow, the curve of the face increased in proportion with the rise of the water. The writer observed closely the action of the structure during the rise of the water for the last ten feet to its highest stage. The movement backward was gradual and appeared to cease when the greatest height of water was reached. The compression of the timbers, under the load applied, should produce this result, and without doubt it did so.

The filling in the dam was necessarily done during the freezing weather of the winter months. To puddle the filling was not practicable; it was intended that the mass of filling should be compact and should not settle to any great extent, as fully 90 per cent. of the filling was of broken stone. The spaces between the timbers being filled with stone and the entire body of the filling in the

cribs being quite compact, it was not thought that the settlement of the material would be of serious consequence. As a matter of fact, the material settled very little in the cribs, even with the free access of water into the structure after the flood. It had not been intended to turn the water into the crib work suddenly and in large volume. It was expected that while the reservoir was being slowly filled sufficient water would find its way into the dam to cause the fine material to find lodgment toward the base of the structure and to fill up the voids in the coarser material of the filling. It must be admitted, however, that this puddling of the material was not deemed essential as a matter of safety for the structure. The more compact the mass of filling, the greater the weight of the structure. The question of thus forming necessary bearing surface for the timber in the cribs to resist compression was not contemplated. The necessary weight of the structure was figured on the basis of loose rock filling only.

The result shows, however, that had the material been thoroughly puddled together, the voids among the stones between the timbers thoroughly filled solid with the fine material, the timbers would in all probability have had sufficient bearing surface to prevent the compression of the timber to the extent that occurred.

From the writer's observation and investigation, it is obvious to him that the supporting walls of a timber crib dam, namely, those parallel with the direction of pressure, should be solid.

This result may be accomplished by compactly puddling the entire mass of filling in the cribs, so that each timber has a full bearing for its entire length. This result can also be accomplished without the puddling process, by the use of timber blocking between the timbers of the crib. The pressure that will be brought to bear on the timbers can be calculated, and the arrangement of the timber in the walls so proportioned as to offer the proper resistance to compression. The walls need not be solid throughout their entire length; but the line of greatest pressure should be fully guarded. Timber blocking need not be used to accomplish this necessary resistance; masonry laid in mortar between the timbers will do as well and will add weight; even stone, if quarried with flat surfaces, can be so laid as to give even bearing surface for the timbers. The use of timber blocking is, however, suggested as being probably the cheapest method of obtaining the necessary rigidity, as well as possibly the surest method of obtaining a uniform flat bearing surface for the timbers of the cribs.

As an additional precaution, the writer would suggest the

use of a system of diagonal bracing within the crib work. The system of blocking between the timbers acts as diagonal bracing against the overturning pressure, but this can be further materially strengthened by a system of braces fastened to the sides of the timber walls of the cribs before mentioned. The writer is of the opinion that, had this system of diagonal bracing been used in the structure herein mentioned, even omitting the blocking as above suggested, the dam would have remained rigid in position. There would have been no partial failure. The weight of the dam was ample to resist the forces that might be brought to bear upon it to move it bodily. Had the compression of the timber been properly guarded against as above suggested, the dam would have presented an immovable body against the forces imposed upon it.

Although, as before stated, sufficient bearing surface may be obtained by a perfect puddling together of the material used in filling the cribs, the writer is of the opinion that, in a crib dam, the safest and most satisfactory results will be obtained by the use of timber blocking between the timbers, instead of any of the other methods suggested for taking care of the compression. The timber blocking can be framed into the timbers, and, by the use of drift bolts, can be made solid and unyielding against any sliding or rolling tendency. The walls of the cribs, parallel with the direction of pressure, will become a series of rigid diagonal braces under this system. This, in the writer's opinion, is absolutely necessary to secure stability in a timber crib dam above 20 feet in height.

The Canyon Ferry dam, near Helena, Mont., is built upon the same general design as the dam herein described. (See section of dam, Vol. XX (1898), p. 335 JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, May.

The dam at Canyon Ferry, however, has but half the height of the section shown in Fig. 1. The arrangement of the timbers in the crib work is the same.

The high water of the June flood, 1898, caused a similar action to take place in this structure. The writer is informed that the crest line has formed a circular arc downstreamward. The greatest ordinate of curvature, as stated to the writer, is $4\frac{1}{2}$ feet from the original line. This structure would come under the head of a low timber crib dam, and no serious results should be caused by the compression of the timber in the crib work. However, the writer is convinced that compression occurred sufficient

to draw the crest backward to its present position. The dam no doubt is now rigid, and has assumed a position of rest and stability.

Sufficient bearing surface has been attained, by the timbers crushing in contact with the stone filling, to offer proper resistance to further compressive action under the pressure that may be applied in the future.

The system of blocking herein suggested would no doubt have prevented even this slight compression and would have held the crest of the dam in position as built. The writer recently had occasion to inspect a timber crib dam built this spring. It is 49 feet high and built of round logs, surfaced where they are in contact. The slope of the faces and of both sides is $\frac{1}{2}$:1. The up-stream face is planked with two layers of 2-inch plank. This crib work is filled with broken granite and with sand or decomposed granite, puddled solidly together. The foundation for this dam is solid rock and the crib work rests upon it. A concrete toe forms a water-tight joint with the planking over the up-stream face. This structure, as it stands, is built of round logs with the filling puddled in. The timbers, however, have compressed, and the crest of the dam has a curvature downstream of about two feet at the greatest ordinate. This structure indicates clearly a compression of the timbers along the line of pressure. The dam was filled with water to the waste way at the time the writer visited it. The dam shows no tendency toward bulging backward. The base is intact; the backward movement of the crest runs out and fails to show but a short distance from the crest height.

The timbers on the back of the dam incline slightly inward, while those of the face have the same inward inclination toward the line of greatest pressure.

These instances are mentioned only as confirming the writer's opinion formed from his investigations of the behavior of the Big Hole dam during the flood.

Before concluding this paper, it may be well to refer to aprons for waste weirs. The standard form of waste weir or overflow for masonry dams is pretty well established on the Ogee or Cima form, taking the water from the crest and conducting it away in an unbroken body. This form might be adopted for high timber crib structures, but the writer has never seen a timber apron constructed on these lines. Where practicable, the flat, sloping apron accomplishes the discharge of waste water with the least disturbance, and it should be adopted when possible.

This is easily done when the dam to be constructed is not too high.

The aprons of the Big Hole dam were so arranged that the column of water passing the crest should be broken by the short aprons and strike the lower apron in the form of a broken column. The result was very satisfactory, with the volume of water passing the crest at the high-water stage this year. The writer, however, is informed that at high water in the Missouri River this season the water reached a height of 5 feet over the crest of the Canyon Ferry dam. The column of water fell on the first apron, jumped clear of the second and struck with full force on the lower apron. This apron, however, was protected by the water cushion above it, or it would no doubt have been completely wrecked by the concussion. This condition should be avoided. The water should be trained downward from the crest, caused to strike the intermediate aprons and not allowed to drop with full force at great distance upon the lower aprons. The construction of the aprons must be very strong to withstand this constant hammer. The width of the intermediate aprons above the lowest apron is not material, so long as the water is carried over the crest in such a way as to take the downward direction of the angle of the points of the aprons, which should be on the same angle or line of inclination, the object being to break the force of the water and not permit the full volume of water to strike the lower apron or any intermediate apron in unbroken column in the form of a direct waterfall.

The summing up of the writer's observations upon the construction of timber crib dams might be expressed in one sentence,—take care of compression of timber by sufficient diagonal bracing.

APPENDIX "A."

The following table shows compression tests on samples of Montana lumber, made by H. E. Smith, M.E., of the University of Minnesota.

The samples were cut from timber that had been in the water, as the object of the writer was to obtain the results on such specimens for compression across the grain.

The pressure was applied gradually. At the point called "crushing" in the table, the resistance of the wood to the crushing force became approximately constant for some little time, and then rapidly increased. It was found that the wood would not give way ultimately, even though the blocks were compressed to one inch in thickness. One block of each kind of wood was compressed to about these dimensions when under a pressure of 50,000 pounds.

Table of Compression.—Montana Lumber, Across Grain.

Lumber.	No.	Size.	Area.	Lbs. Crush'g Load.	Lbs. per sq. yard.	Lbs. Ulti. Load.	Lbs. per sq. inch.
Montana Red Fir..................	1	4″x3.46″ x3.46″ thick.	13.84	8,000	578.0	30,000	2,167.6
" " ".................	2	"	"	9,120	658.9		
" " ".................	3	"	"	8,100	585.2	50,000	3,612.8
" White Pine.............	1	"	"	5,600	404.6	30,000	2,167.6
" " ".............	2	"	"	5,600	404.6		
" " ".............	3	"	"	5,700	411.8	50,000	3,612.8

APPENDIX "B".

Contract Prices.

Earth and loose rock excavation below water, per cubic yard..........$1.00
Earth and loose rock excavation above water, per cubic yard......... .40
Power house excavation above water, per cubic yard.................. .30
Power house excavation below water, per cubic yard.................. 1.00
Stone filling in crib work, per cubic yard.......................... .75
Solid rock excavation, per cubic yard............................... 1.00
Stone masonry cement furnished by the company, per cubic yard..... 5.70
Concrete above water furnished by the company, per cubic year...... 4.05
Concrete below water furnished by the company, per cubic yard..... 5.88
Back-filling of earth, per cubic yard............................... .25
Lumber in place for labor only, per 1000............................10.00

These prices include the hauling of all material necessary for the work, such as cement, lumber and iron, from the railway station three miles distant from the work.

DISCUSSION.

Mr. E. H. MacDonald.—The necessity for careful consideration of the design and construction of dams for power and storage purposes has been brought prominently before the engineering profession in Montana during the past two years. The amount of capital required for the construction of this class of structure is necessarily large, and the chances of loss, or even of financial wreck, due to failure.

As examples of large undertakings of this character, I might refer, in addition to the Big Hole dam, now under discussion, to the dams built for storage purposes by the Anaconda Copper Mining Company, near Anaconda.

The writer has read with much interest the paper presented by Mr. Parker, describing the timber crib dam constructed for the Montana Power Company, across the Big Hole River, near Divide, Mont.

A few days after the partial failure of the Big Hole dam, the writer was discussing the subject with Mr. Charles W. McMeekin,

Associate Member American Society Civil Engineers, who had examined the structure, and he at once and unqualifiedly attributed the failure to the crushing of the timber, because of insufficient bearing surface for the stresses that must have occurred; and, until the time of Mr. Parker's paper, the writer was not aware that there was any doubt as to the causes leading to the failure of the structure.

The author states that the resultant of pressure, at a point 60 feet below the crest, is 148 tons for one foot of section. I presume that by one foot of section is meant an area one foot wide and of a length equal to the full width of the dam at a depth of 60 feet below the crest. This 148 tons resultant pressure is correct under certain assumptions as to weight of material used for filling. The author seems to have assumed that his pressure of 148 tons is concentrated on an area of 100 square inches at the point of intersection of the line of the resultant, with a section of the dam 60 feet below the crest. He thus arrives at a resulting pressure of 2960 pounds per square inch of surface, and, on his further assumption that "each wall of the 8-foot crib is to carry its full load under the above conditions, we would have eight times the above load," he arrives at a resulting pressure of 23,680 pounds per square inch, or about 1700 tons per square foot, or nearly 50 per cent. greater than the ultimate crushing strength of the best granite. As a matter of fact, this 148 tons resulting pressure is distributed with varying degrees of intensity over an area one foot wide and of a length equal to the thickness of the dam at a point 60 feet below the crest. If this resultant cuts the base of the section at its middle point, we would have a resulting pressure of about 3800 pounds per square foot (assuming the thickness at this depth to be 78 feet), and on the hypothesis that one block of 100 square inches bearing surface supports an area of one entire crib, or 64 square feet, we would have a pressure of 2432 pounds per square inch, a stress more than sufficient to cause a failure of the pine blocking.

The results of the test which the author had made, in order to ascertain the crushing strength of pine and fir timber, agree very closely with the results obtained in the United States Government tests of 1880. It was here also found that fairly well-seasoned white pine would compress from 1-48 to 1-24 of its height under a load of but 500 pounds per square inch. Doubtless, when green or wet, the compression would very much exceed the maximum here given, indicating that a high degree of rigidity cannot be expected in a structure of this class.

Mr. Page.—At our last annual meeting I asked Mr. Parker some questions in regard to the Big Hole dam, which he was building at that time. I asked Mr. Parker these questions because my experience is that engineers generally do not realize the pressure brought upon these dams in a sudden flood of water where the dam is not perfected, and it seemed to me something of an experiment building a timber crib dam like the Big Hole River to a height of 60 feet, as in this case. I would ask the members whether such a height is not unusual for a crib dam?

Mr. Carroll.—I believe the Big Hole dam of the Montana Power Company is one of the highest, if not the highest, crib dams that ever has been attempted. I believe that, if the dam had been constructed in any other way, it would have failed under the conditions of last spring. As it was, the binding of the timbers together, and the thorough settling of the filling when the water rushed into it, settled the whole thing down into a solid mass and saved its complete failure. I do not know of any construction that can show better staying qualities than the dam on the Big Hole has.

I believe the dam first moved downstream by the rolling of the logs at right angles to the direction of the pressure, thus throwing the whole structure out of equilibrium, after which a settlement took place, and the timbers, not being of sufficient strength, having only one intersection at the corners, and no supports between, cracked and crushed until the whole mass became solid. This was one of the reasons why I placed the fillers in the dam constructed for the Water Company, which not only gave a greater bearing surface to withstand the pressure and prevent crushing of the timbers, but also had a tendency to prevent any rolling motion of the logs at right angles to the pressure.

It has occurred to me recently that had the spillway of the Big Hole dam been built through the solid rock around the end of the structure, and if the spillway and fore bay had not been placed in the center, as they were, the dam would not have failed.

Mr. Wilson.—Several years ago I built a crib dam some 50 feet in height, for which I was unfortunate enough to have no foundation, and which has been entirely successful, I believe. It is now in use and it was erected at a very small cost. My observations on that dam were such that I would engage to build a similar structure 100 feet high without fear of disaster. This was in Idaho, and we had limitations as to means and as to transportation, and we had to improvise almost all our mechanical apparatus. In answer to Mr. Page's question, I would say that there is abso-

lutely no doubt—certainly not in my mind, and I believe not in the minds of most of those who have had experience in timber structures—that it is the safest possible form of construction, because of the fact that when it fails it necessarily has to fail gradually. An earth structure goes in a second. A masonry dam is apt to do it, but a crib dam, with the possible settling into place of filling contained within the cribs, makes the failure practically a very gradual one. As far as the Big Hole dam is concerned, its failure is primarily due to the fact that it was cut in two, as Mr. Carroll suggests. The spillway around the side would have obviated anything of that sort, and, so far as that is concerned, I am credibly informed that, had a State engineer had supervision of those plans, the members of the company would never have been allowed to alter the original plan submitted by Mr. Fanning. That is something that has not been generally discussed; and the responsibility for the partial failure no doubt rests, not with Mr. Fanning or upon a weakness in his plans, but upon their alteration with a view to economy. The result was a sacrifice of property.

Mr. Bradford.—What was the material under the dam where there was no bottom?

Mr. Wilson.—Broken rock and earth, and of such a character that it was practically a quicksand with big boulders in it occasionally. I had to place the sheet piling,—could not drive it, and it was the most expensive and hardest work in the whole structure, because of the fact that we had no appliances. We put in a double row of boarding and puddled between with fire clay. The slope went back two to one. There never has been any leak nor any trouble. It was an absolutely water-tight vessel.

Mr. Kinney.—I was glad to see, yesterday, that, in the dam at the Ferry, they were putting in bolts about 5 feet in length and $1\frac{1}{2}$ inches in diameter, coupling together perhaps four or five depths of logs and clinching them perfectly. I think that if that had been done in the dam it would surely have prevented any rolling of the logs. They could not have gotten apart enough to turn up. It is a very simple expedient and it would have been a great help. A few of those bolts scattered around here and there would have held it together in good shape.

Mr. Bickel.—There is a solid floor in the Canyon Ferry dam and I was told that at one place, where they opened it up, some of those timbers had rolled or turned about 45 degrees.

Mr. Bradford.—What is the life of timber in a dam of this character that is not covered constantly by water?

Mr. Carroll.—The Colorado Flume Company put in some dams on Basin Creek, I think, in 1882 and in 1891 (they were not used after that year) they were in excellent shape.

Mr. Bradford.—Is that sawed timber?

Mr. Carroll.—No, round logs with the bark on. The logs seemed to be rotted under the bark, but not in the core. We found a great many sound logs there.

Mr. Wilson.—Thoroughly protected from the atmosphere?

Mr. Carroll.—They were old-style logging dams, 12 or 15 feet high, built in the shape of a triangle.

Mr. Wilson.—More as a retaining wall, with a filling between?

Mr. Carroll.—Yes, sir, about 2 feet of earth filling on water face. Of course, when the reservoirs filled, they were kept damp. The reservoirs were emptied in the winter. In that way they had the very worst treatment they could have.

Mr. Bradford.—In 1889 I built a diverting dam of fir logs with the bark on, and in 5 years I had to remove them, as they were rotted.

Mr. Sizer.—I would like to ask any of the gentlemen who have given it attention what they consider the present strength of the Big Hole dam,—whether it has assumed the condition of strength in which it is reasonably likely to sustain itself?

Mr. Wilson.—I believe some additional work has been devised which adds very much to its strength. What its details are I do not remember exactly, but the base was practically added to very materially. They took off 30 or 40 feet of the top, rebuilding it from that point, and practically rebuilding the entire dam excepting the concrete, core and body as it existed when we saw it, below a point 30 feet, I think, from the crest.

Mr. Carroll.—They have also taken out the large fore bay and put in a penstock. This, I think, will materially increase the strength of the dam. I understand that much trouble is generally experienced in water plants in governing water wheels. An article in one of the engineering papers not long ago spoke of trouble arising from the fact that the water in the penstock had a movement or swish back and forth, which completely demoralized everything while it lasted. The engineer of the Big Hole Company wanted the fore bay in order to prevent that, and thought he could accomplish better results. The fore bay was the weak point in the Big Hole dam. That is where it first broke and gave way,—at the edge of the fore bay. They have been putting in a steel penstock protected by masonry, and as far as the structure

itself looks, it seems perfectly solid and as if it has finally settled. The only danger I foresee with the dam is the same trouble they had with the Canyon Ferry dam last year,—the water shooting over the top of the spillway and striking the bottom with such force as to wash it out and make a settlement there in the lower toe of the dam. I think the new incline apron at Canyon Ferry is much preferable to the steps in that regard. If they can keep the stream of water solid over the structure, there is not so much danger. It seems to me not a bad idea to make a water cushion for the overflow. They could get several feet of water to catch the overflow and I think materially reduce the chances of washing.

Mr. Bickel.—I understand there was a great deal of pounding of the dam when the water fell on these timbers, and it seemed to shake the whole structure.

THE CONSTRUCTION OF A CRIB DAM FOR THE BUTTE CITY WATER CO.

By Eugene Carroll, Chief Engineer Butte City Water Company, Member of the Montana Society of Engineers.

[Read before the Society at its 12th annual meeting, January 12, 1899.*]

The following short description of a crib dam built by the writer last year is not intended to be of any great practical benefit to the profession, except in the hope of callng forth a discussion as to the best method to be followed in the construction of similar structures. The writer claims nothing original in the design, but, from observation during and after construction, several improvements on the original have suggested themselves to him; and these ideas may be of some value to others who find themselves in a position similar to his.

The Butte City Water Company has had in the past a great deal of trouble with the annual spoiling of its stored water, and the writer has spent the last four years in trying to remedy the trouble. The cause of the trouble is undoubtedly the growth and decay of vegetable organisms, which develop during the summer months and lie dormant during the winter. The writer spent an interesting week discussing the similar troubles which they have had in Boston, and investigating the means employed at that place to remedy the evil. The Metropolitan Water Board has spent enormous sums in cleaning out the bottoms of its storage reservoirs, and in all new reservoirs now built the surface soil is removed to a depth where analysis shows not more than 2 per cent. of vegetable organisms. The good results are plainly visible in the complete records kept, though, notwithstanding the care, the writer is informed that the trouble still appears at times, though in a much less degree. The Butte City Water Company has thoroughly cleaned the bottom of its storage reservoir, but the writer believes that many of the obnoxious germs are washed in each year during the first flood waters, and for that reason has always advocated the construction of a settling basin above the present storage reservoir. This work was authorized in the spring of 1898, and the reservoir was completed about July 1 of that year.

In designing a dam for this settling basin the writer was hampered by several considerations. Masonry was too expensive; there is no suitable material in that vicinity for an earth dam, and

*Manuscript received March 3, 1899.—Secretary, Ass'n of Eng. Socs.

a rock-filled crib was finally adopted. A vertical face appealed to him as the best form from the fact that timber was scarce, and a more stable structure could be built with less timber. After the experience of the Montana Power Company's dam on the Big Hole he changed his views in this regard and adopted a sloping face.

GENERAL DIMENSIONS.

The dam is 319 feet long on the crest, including the spillway, and the crib work is 42 feet high. It is built of round fir logs, in cribs 8 feet square. The upper face has a slope of 16 feet horizontal to 39 feet vertical, the lower face 24 feet horizontal to 42 feet vertical. The water face is sheeted with 2-inch plank, laid double, and breaking joints to make it water-tight. This lining extends to bed rock in front of the concrete core wall.

A concrete core wall 3 feet 8 inches thick is built under the inner toe of the dam, extending from bed rock to about 12 inches above the level of the bottom of the crib work.

A 12-inch cast iron blow-off pipe is laid through the center of the structure, with a valve at the lower end and a crib protected by a screen at the upper end.

The crib work is 48 feet wide on the bottom and 8 feet wide at the top.

An earth fill is built on the back of the dam, on a slope of $1\frac{1}{2} : 1$.

CRIB WORK.

The cribs, 8 feet square, are of round fir logs stripped of all bark, and not less than 7 inches in thickness at the small ends. The logs were lapped at all intersections, and at every contact a $\frac{3}{4}$-inch drift bolt binds them together. Between the logs, running in the direction of the pressure, fillers were inserted, as shown in the plan. These fillers were firmly held in place by drift bolts, and were put in to make a greater bearing surface to withstand the pressure, and also to prevent a rolling of the cross logs when the pressure was received.

At each end of the structure the logs were anchored to the bed rock when possible.

The logs forming the water face were hewn to a true surface to receive the sheeting, the lowest one being imbedded in the concrete core to form the knuckle where the slope joined the vertical sheeting of the core wall.

FILLING.

The cribs were filled with broken rock, decomposed granite being flushed in to thoroughly fill all the interstices. Great care was exercised in placing this so that every part of each crib was thoroughly filled. The material was put in in thin layers, spread by hand, and a liberal amount of water was used to settle it thoroughly and flush in the interstices. Owing to the fact that much of the excavation from the bottom of the reservoir had to be deposited below the dam, the filling could not be carried up in regular layers along the whole structure, as was desired by the writer. However, as will be shown further along, this method of filling one side first did not have any serious effect, as the whole structure settled equally when finished.

CORE WALL.

Along the inner toe of the crib work, extending to bed rock, a concrete core wall, 3 feet 8 inches thick, with double 2-inch sheeting along the upper side, was built to prevent any leakage under the structure. This concrete was made in the proportion of 5 broken rock, 3 sand to 1 of cement, and carefully rammed in place. The concrete was carried to about one foot above the base of the crib work, to support the lower log to form the knuckle of the sheeting. At the west end this core wall was carried to the top of the structure and extended to the back, as shown in the plans, to form the spillway.

The cement used was Utah Portland.

BLOW-OFF PIPE.

A 12-inch cast iron pipe extends under the dam to empty the reservoir when the water is needed in low water season. This pipe was laid on a concrete foundation extending to bed rock from the intake to the valve, and then imbedded to a depth of 6 inches in concrete. At regular intervals the concrete was increased 6 inches in width and height, to form collars to prevent leakage from forming a regular channel along it. The upper end of the pipe opens into a timber crib 4 feet square, on which an iron grating is secured to prevent any *débris* from stopping up the pipe. This crib is carried 4 feet above the bottom of the reservoir, but it can be opened at any time to sluice out when this becomes necessary. Where the pipe enters the shetting of the core wall a collar, 6 inches thick, of neat cement is formed, by grouting, to prevent leakage around the pipe at that point.

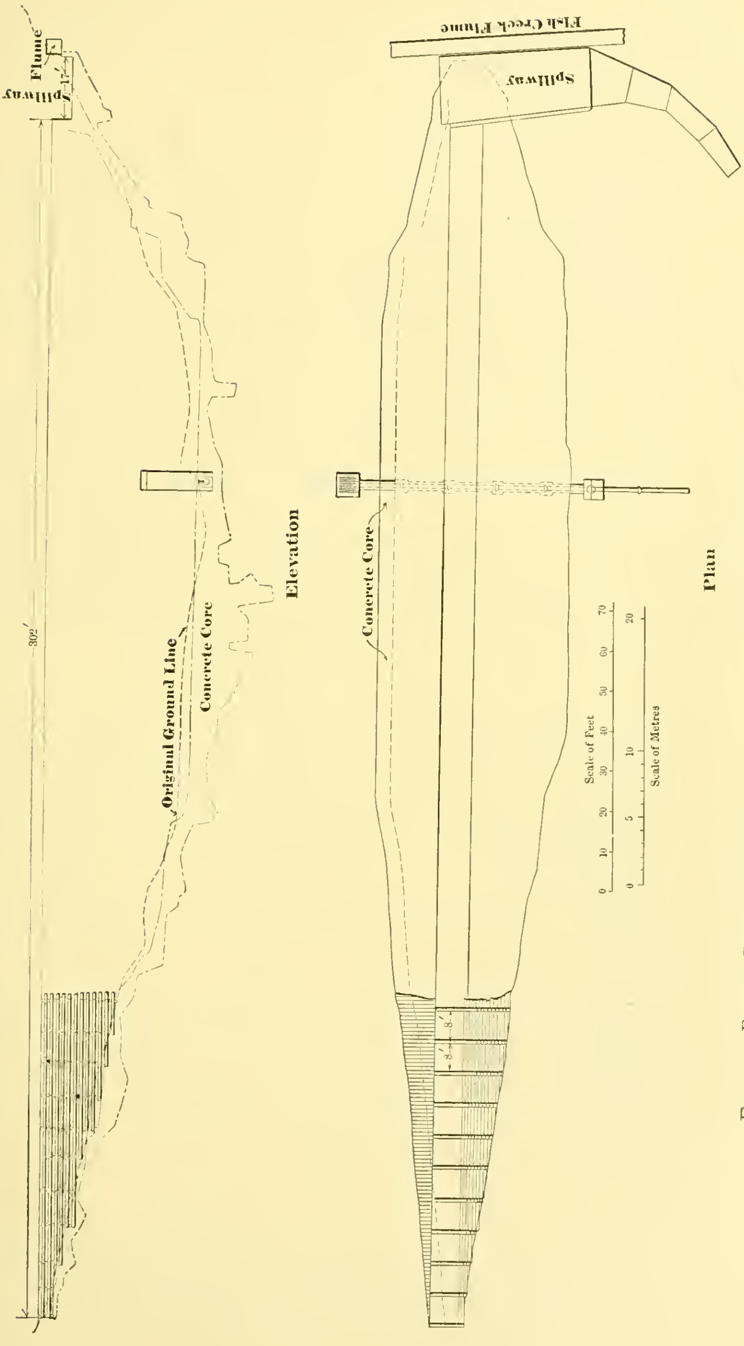


Fig. 1. Butte City Water Company's Crib Dam for Reservoir No. 2, Basin Creek.

In addition to supporting the valve by concrete built back of it, the valve is anchored to the pipe by two ¾-inch rods extending 24 feet back into the concrete.

SPILLWAY.

The spillway has a clear width of 17 feet, the bottom being 5 feet below the crest of the dam. It is built around the west end of the structure, and is so constructed that the overflow can be turned either into the creek or into a flume which extends from the head-waters of Fish Creek to the main reservoir below, known as the Fish Creek flume. This Fish Creek flume extends around the reservoir, and is enlarged at this point so that it can be used as an additional spillway if necessary.

The flumes and spillway are so arranged that the reservoir can be entirely cut out of the system, or the overflow can be used; or all water, including Fish Creek, can be turned through this reservoir.

The spillway is cut through a point of solid rock, which extends out beyond the west end of the dam and empties into a creek which flows into the main creek about 300 feet below the toe of the dam.

SHEETING.

The water face of the dam is protected by 2-inch planks spiked on to the crib work in two layers, breaking joints in every direction. At the kunckle where the sloping face is joined to the vertical sheeting in front of the core wall an additional plank was spiked over the joint horizontally, and all seams were carefully calked with oakum and poured with hot asphalt.

A puddled fill of earth and gravel mixed was then made against the dam, extending about 8 feet above the knuckle, and about 10 feet wide on the bottom.

The outside seams of the sheeting were then loosely calked with oakum to the top. The calking and puddling about the knuckle were left till the last, when most of the settling had taken place; and we were thus assured that there would be no danger of the joints opening or the facing settling.

BACK FILL.

As it was necessary to waste below the dam, this waste material was used to make a back fill on the lower side of the structure. This served to strengthen it, and it will also protect the timber from the action of the sun and from the danger of fire. At completion

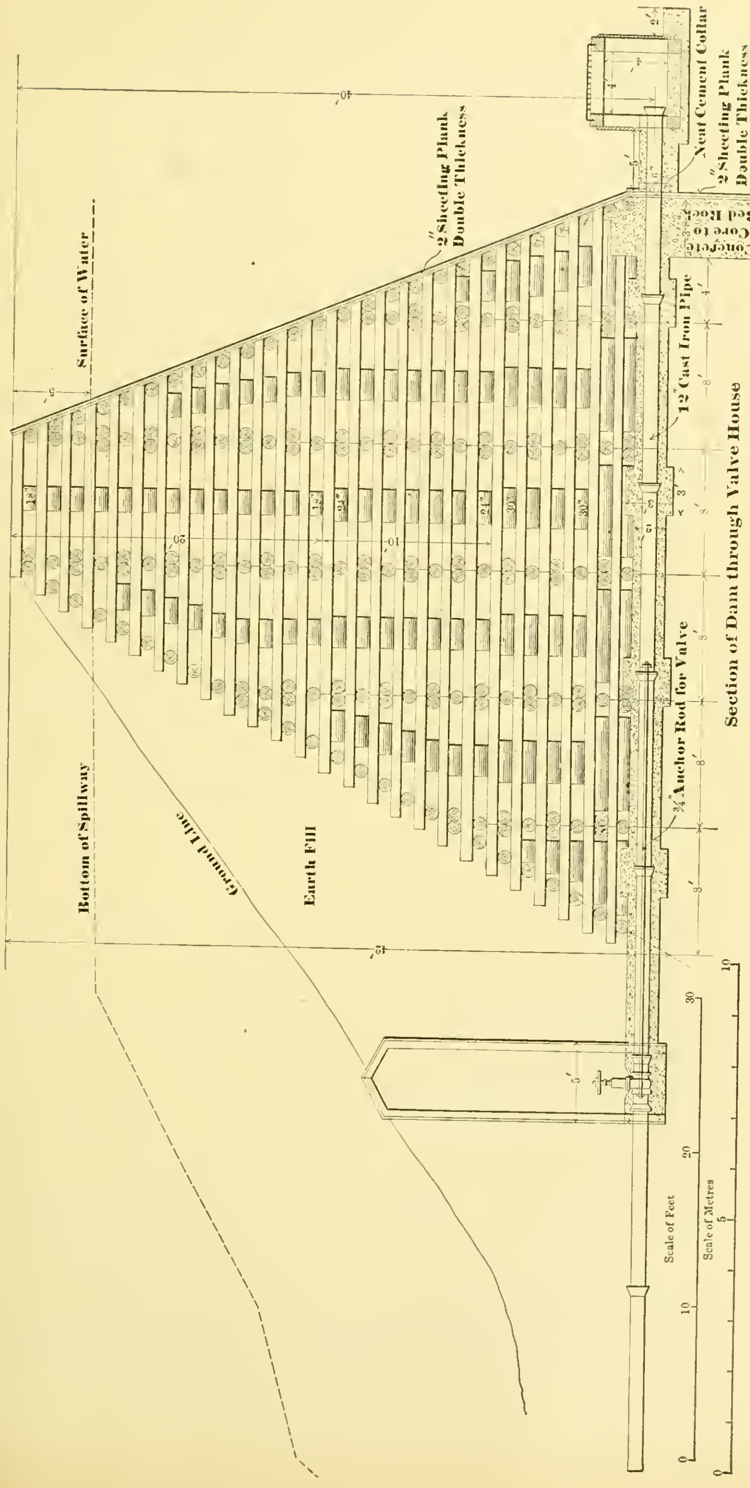


FIG. 2. BUTTE CITY WATER COMPANY'S CRIB DAM FOR RESERVOIR NO. 2, BASIN CREEK.

this fill extended only about half-way up the structure, but it was afterward carried clear to the top, partially to allay the fears of ranchers living below the structure, who were much worked up over the trouble experienced on the Big Hole with a similar structure.

A box drain is laid under the back fill to carry off any leakage through the face.

CLEANING OF BOTTOM.

All surface material was carefully removed from the bottom of the reservoir to a depth sufficient to get below all vegetable organisms. The material from the upper end of the reservoir was deposited in two draws, so as to prevent the formation of any shallow places in the reservoir. These fills were carried up on a regular 3 : 1 slope, and it is the writer's intention to cover their water slope with gravel eventually.

GENERAL REMARKS.

The matter given the most serious thought in designing this structure was settlement of the structure within itself. The foundation was perfectly solid, so that there was no fear of settlement there. The writer visited the dam on the Big Hole, and finally decided on the following changes from that design, in order to prevent a similar occurrence with this structure: Instead of butting the logs at intersections, all logs were lapped, thus giving nearly double the bearing surface at the intersections. Fillers were placed between the logs running in the direction of the pressure, not only to increase the bearing surface of the logs, but also to resist any tendency in the parallel logs to roll when the water pressure was applied. The writer believes that a sloping face is greatly preferable to a vertical one, because, as the water rises against the structure, the resultant pressure has more of a tendency to press the structure together and toward the foundation. With a vertical face there is a much greater tendency to push the structure over and to cause a rolling of the timber forming it.

The object attempted in the design of this structure was to make the timber bents, which receive the pressure of the water, sufficiently solid to hold the facing in place even without the assistance of the filling. On building this dam we had considerable trouble in placing the fillers, and I believe a better structure could be built by butting the logs running in the line of pressure and lapping the cross logs. This arrangement would give the same bearing surface at each intersection, and would bring the logs vertically one above the other, thus getting the best result from the fillers

between. As stated above, the east end of the dam was filled first, to allow a passage through the dam for the bottom cleaning and to avoid delaying the work. The east cribs were filled to a depth of about 30 feet before any filling was placed on the west end. The weight of the filling settled the structure considerably, but the writer was pleased to find that when the west end was filled that end also settled, so that there was a regular settlement from end to end, depending upon the depth, the back logs taking a regular curve from each end. When the reservoir was filled the structure continued to settle in regular form until, upon its final set, the top of the sheeting at the center was about 2 feet 9 inches out of the straight line, coming in a regular curve to zero at each end.

The logs in the back showed no sign of movement or undue strain, and all settlement seemed perfectly regular and steady throughout. On August 1, with the water within 6 inches of the overflow, the top of the dam, at the point of greatest depth, had settled back 2 feet 3 inches; while on October 1 it reached the maximum of 2 feet 9 inches.

The leakage through the face was considerable at first, but soon became less; and for the past four months has remained steady, amounting to about 30,000 gallons per day. It is the writer's intention to nail battens on the seams as the water goes down this winter, hoping thereby to reduce the leakage considerably. At some future time an earth fill will probably be placed on the water face, to keep the structure absolutely water-tight and prevent the sun from drying the facing and opening the seams each year.

DISCUSSION.

Mr. Wilson.—If not disclosing any secrets, Mr. Carroll, can you give us an estimate as to what this dam of yours cost?

Mr. Carroll.—The work, with the exception of the back fill, was done by contract at the following prices: Crib filling, 75 cents per cubic yard; crib work, 12 cents per linear foot; drift bolts, 4 cents per pound; lumber in place, $30 per thousand; concrete, Utah Portland cement, $7.00 per cubic yard; excavation for dam and core wall, 50 cents per cubic yard; wet excavation, $3.00 per cubic yard.

The whole structure cost, including the engineering and the back fill, about $32,000.

In regard to the back fill, I do not claim that it is a good engineering proposition to put a fill on the back of a dam, as the leakage through the dam is liable to wash it away and give considerable trouble. It was not my intention at first to put this fill

in, but in order to allay the fears of the people living below the structure I decided to put it in partly for effect, as it makes the structure look much stronger.

There is one other good reason for placing a fill on the back of a timber structure, and that is to prevent the danger of the dam being seriously injured or caused to fail by forest fires. As the dam is in the mountains, and no one living near it, a forest fire might start at some time, and before we could get to it might seriously injure the dam, and even cause it to fail.

There is a box drain under the fill connected along the foot of the timber structure to carry away the leakage through the face.

I believe Mr. Wilson designed a crib dam something similar to this, only he placed his slope next to the water on an angle of about 30 degrees.

Mr. Wilson.—In the dam I constructed the slope next to the water was two to one, and the logs were carried parallel to the face, so that practically the pressure on that face was at right angle to the courses of the logs. There was another interesting feature about the structure I built. I had an opportunity to make a fill that was very effective, and if ever such an opportunity presents itself I would earnestly recommend it. I built a dam on a stream above the main dam about 40 feet high, from which we laid a line of hydraulic pipe on the surface to a gravel bed just above the site of the main dam. By this means we sluiced the gravel in as filling, and it gave a very satisfactory result. It filled every space between the logs, and made practically a continuous blocking. The filling was so hard after it was there that I could not drive a pick into it a quarter of an inch.

Mr. Carroll.—Hydraulic dams have been built, I believe, in several places in Arizona in the past few years, running the material into the dam site by water and carrying it up in regular slopes. In our investigations during the past summer, looking toward the increase of the water supply of Butte, we found a site in which the conditions were excellent for making such a dam, and it was our intention to make it by the hydraulic method. I afterward had to abandon it, however, on account of the great depth of bed rock, which made the core wall too expensive.

For an economical dam I like the type which are being constructed in several parts of California at the present time, where a dry wall face is carried up next to the water and made water-tight by either planking or the use of asphalt or concrete.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXII. MAY, 1899. NO. 5.

SEWERS LAID UNDER AQUEDUCTS AT NEWTON, MASS.

BY HENRY D. WOODS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, January 25, 1899.*]

IN the autumn of 1896 it became necessary to connect the local sewers that had been built in Newton Highlands during the summer with the main sewer coming up the Cold Spring Valley by passing under both the Sunbury River conduit and the old Cochituate aqueduct, which supply the city of Boston with water. These two structures cross the upper end of the valley on embankments with no provisions for allowing the surface water to pass under them, so that in the spring of the year considerable water accumulates at the foot of the slopes on the south side, causing complaints from the landowners that have built houses near by on the lowlands.

As eventually all the drainage from quite a district must be taken down the Cold Spring Valley, it was decided to put under the water works a culvert that would accommodate both the future drain and the sewer.

It was very important that, in carrying on the work under the Boston water supply mains, no settlements should take place that might endanger these structures, and it was not considered safe to leave any timbers in the ground under them after the work was completed, which might eventually decay and cause settlement. Mr. Desmond FitzGerald, the engineer of the Boston Water Works, who had charge of these structures, suggested the use of a long steel boiler shell or cylinder driven under the aqueduct, and

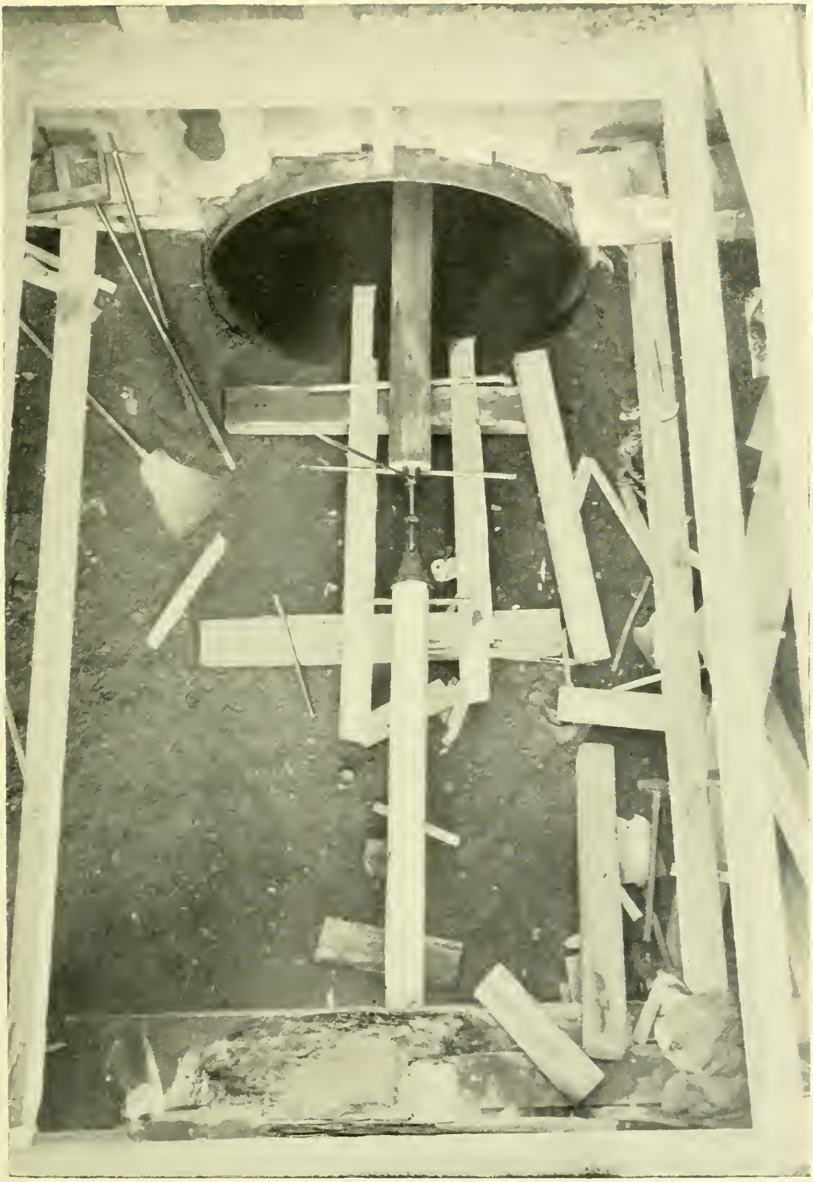
*Manuscript received April 6, 1899. Secretary, Ass'n of Eng. Socs.

it was decided to try the experiment first under the stronger structure, the Sudbury River aqueduct, which is of modern construction, of a horseshoe shape of solid brick masonry and concrete.

The brick drain required was 30 and 36 inches in diameter, and the sewer was a 12-inch pipe with 6-inch underdrain. The grades were such that a flattened section could be used on the drain, and both the drain and sewer could be placed inside a 5-foot tunnel. The excavation being in good dry gravel, we were allowed to run the open ditch to within 10 feet of the structure. This would leave 36 feet to be tunnelled. The grade of the top of the drain would be 7 feet 1 inch below the bottom of the aqueduct. Six steel cylinders were ordered of $\frac{3}{8}$-inch boiler steel, single riveted, and from 5 feet 6 inches to 6 feet 5 inches long. The diameters varied from 5 to 6 feet, with two inches variations on each.

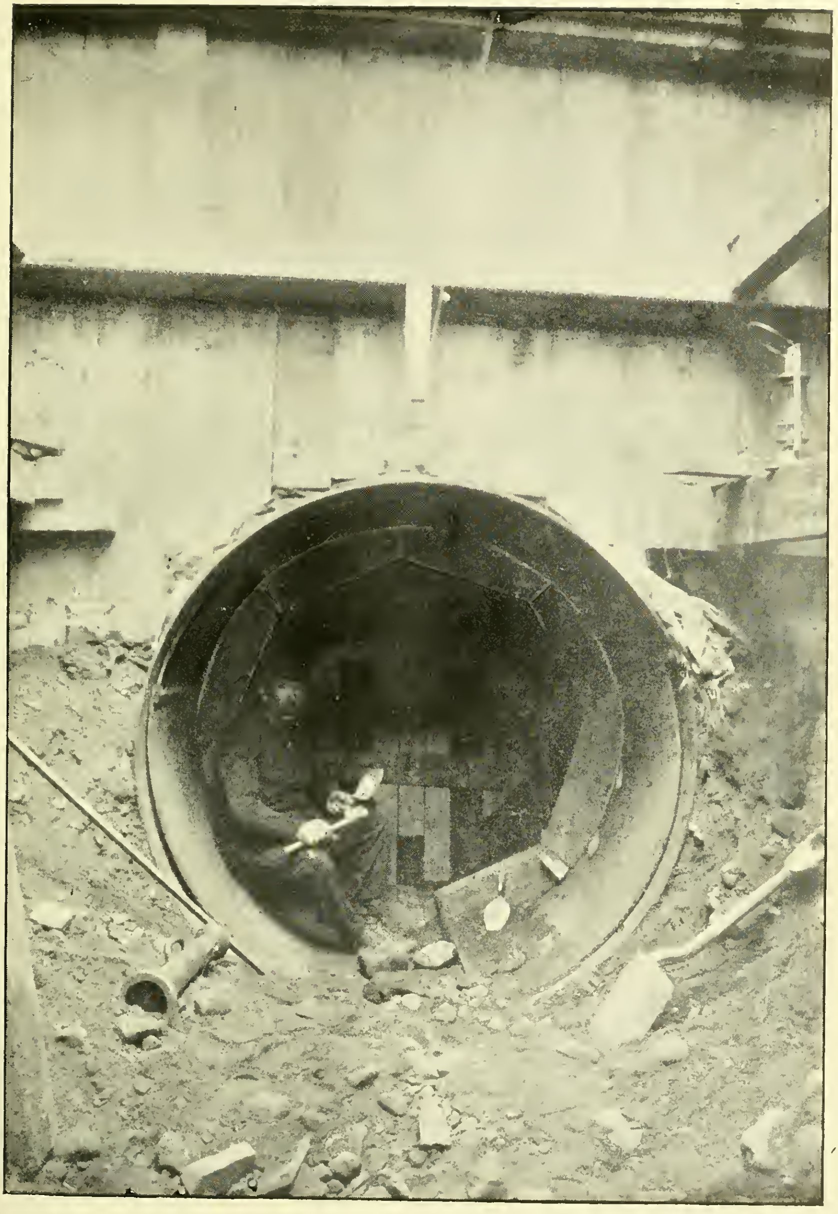
The flexibility of the metal was such that, when lying in the open field on their sides, they sagged an inch in diameter by their own weight. When placed in the ground, the surrounding gravel would keep them in shape, so that a circular frame or curb, made of 6 x 8-inch stock, was placed in the center of the cylinders and wedged in place so as to preserve the true shape. But, being open in the middle, it allowed free passage from one side to the other.

The regular trench was dug out 6 feet wide, but a 13-foot chamber was excavated on each side of the conduit, properly sheathed and braced, and bulkheaded towards the conduit. The largest cylinder was lowered into the chamber, an opening was made in the bulkhead at the proper grade and the cylinder was gradually forced into the gravel, horizontally, by means of a jack-screw, as shown in the cuts. The jack-screw was applied to the middle of a timber placed across the end of the cylinder by means of a horizontal 6 x 8-inch hard pine stick laid on iron pipe rolls. The jack was 18 inches long, with a $1\frac{1}{2}$-inch screw. As soon as it had been run out some 6 inches it was turned back, more blocking was put behind it, and, if the cylinder was not going in on line or grade, the position of the block across the front was shifted so as to correct the defect. To observe any deviation from line or from grade, a transit was set up in the trench a short distance back. As fast as the cylinder advanced the material at the front was dug out and thrown back. This was coarse, loose gravel, with occasional stones as large as 8 x 10 x 12 inches, but mostly pebbles and cobbles as large as one's fist. A man was constantly watching the cutting edge, so as to fill up any openings left in the gravel back of the cylinder by dropping out of cobbles or stones. Dirt was mostly used for this purpose, except for large holes, when some



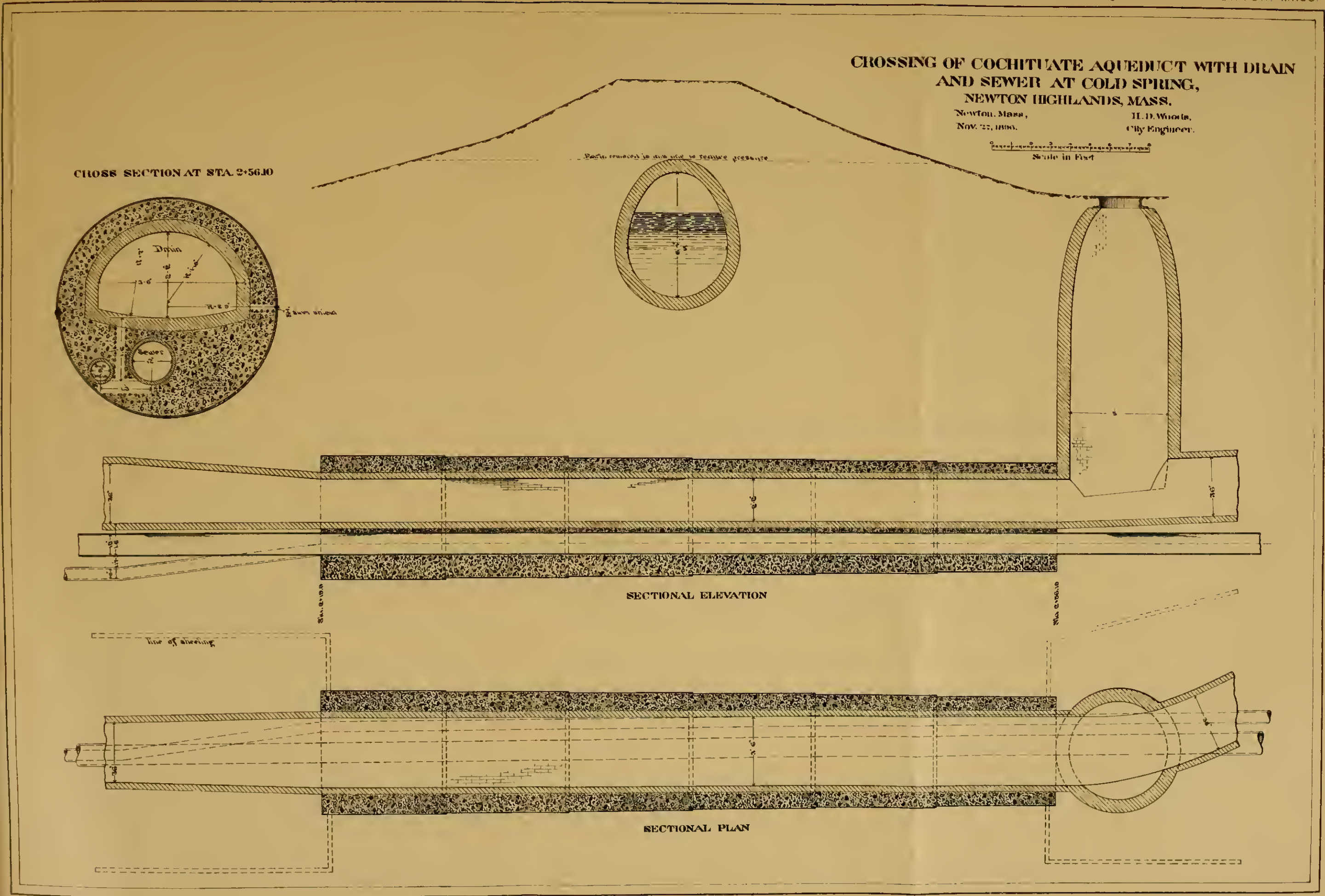
Geo. H. Walker & Co., Boston.

VIEW LOOKING DOWN INTO WORKING CHAMBER, SHOWING JACK-SCREW AND FOLLOWER FOR PUSHING STEEL TUBES UNDER THE BOSTON WATER WORKS.



Geo. H. Walker & Co., Boston.

VIEW SHOWING STEEL TUBE TUNNEL INSERTED UNDER BOSTON WATER WORKS.


CROSSING OF COCHITUATE AQUEDUCT WITH DRAIN AND SEWER AT COLD SPRING,
NEWTON HIGHLANDS, MASS.
Newton, Mass.,
H. D. Woods, City Engineer.
Scale in Feet
CROSS SECTION AT STA. 2+56.10
Drain
Sewer
SECTIONAL ELEVATION
SECTIONAL PLAN

concrete was tamped in so as to leave no cavities back of the cylinder. When the first cylinder was pushed completely into the gravel the center curbing was removed; the next smaller cylinder was introduced, after trueing it up with the curb, and the jack applied to this, pushing it through the larger cylinder.

The force employed consisted of four men, one foreman and an inspector. An agent of the Boston Water Board was constantly on hand to supervise the work, and arrangements had been made to communicate with the Boston offices in case of any accident that might affect the water supply, and allow of its being shut off at once.

After getting used to the work, a cylinder was forced in place in one working day. The first one was started on November 7, and the sixth one reached the other bulkhead on the 19th. The greatest variation in line or grade at any one time was slightly over one inch. The six cylinders weighed about five tons, or 297 pounds per foot of tunnel, as the cylinders were allowed to overlap about five inches. They cost $3\frac{3}{8}$ cents per pound, or $9.32 per foot.

All this work was in dry gravel, no water being encountered.

After this tunnel was cut through, we were allowed to try the same system under the old Cochituate aqueduct, which was known to be leaky and rather weak and shaky. A larger section was required here, on account of the drain, but the cylinders were ordered with but one inch variation, so that the diameters varied from 5 feet 6 inches to 6 feet only, and were $\frac{1}{2}$ inch thick.

The shells were made thicker, for the reason that test pits had shown that the ground water was 8 inches above the grade of the tunnel, and it was thought that there might be leaks in the aqueduct.

The Water Department intended to inject Portland cement grout through the top of the shell after it was in place, in order to fill up the interstices, and, if possible, stop the leakage. As it was late in the season, after the fill was removed from the top of the aqueduct, this was covered with manure and canvas to protect it from freezing.

The first pipe was started on November 28. Owing to the gravel being wet, some difficulty was encountered in the weight of the gravel, which tended to tip the cylinder down at the front, and more adjustments had to be made in applying the jack, so as to keep the cylinder in line and grade.

When the second cylinder was introduced, owing to their being but a single inch reduction in diameter, it was necessary to

use a steel wedge at the front, in order to keep the inner cylinder from binding in the one previously put in place.

By lowering the pump-well on the north side of the aqueduct and drawing the water into another basin, it was possible to reduce the level of the ground water in the tunnel. After this the progress was more rapid. The last cylinder was placed December 11. On this second tunnel the greatest variation from grade was 2 inches and the greatest variation in line 3 inches.

In both cases, as soon as the cylinders were in place, the pipe sewer and underdrain were put through, bedded in concrete, the top of the concrete being leveled off to receive the brick invert of the drain. This was 4 inches of brick work, which was carried clear through the tunnel.

To place the arch, work was begun in the center and run each way, on 4-foot centers, concrete being filled in outside of the brick work as fast as the work progressed.

The cost of the steel cylinders and excavating the tunnel were charged to the drain, this being the more important work. The charge to sewers was simply the cost of construction of the line of sewer and sub-drain. The cost of putting through the tunnel may be stated as follows:

	Sudbury River conduit.		Cochituate conduit.	
	Lbs.	Cost.	Lbs.	Cost.
Cost of steel shell delivered.	10,700	$356.50	13,700	$457.25
Cost of labor and material used in placing the shell, excavating, pumping, etc..		133.04		189.70
Total cost of tunnel.....		$489.54		$646.95
Length of actual tunnel.....		36 ft.		37.1 ft.
Cost per linear foot of tunnel		$13.60		$17.44

THE MANUFACTURE AND INSPECTION OF CAST IRON PIPES.

By Thomas H. Wiggin, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 20, 1897.*]

It was my good fortune to spend eight months of the year 1896 in work for the Metropolitan Water Board, of Massachusetts, at two of the large pipe foundries in the vicinity of Philadelphia, and the President has asked me to present some description of the processes of pipe making and inspecting.

Methods of Casting.†

Every casting, whether a pipe casting or other, is made by one of three methods, the "green sand," the "dry sand" or the "loam." These methods are so distinct to the founder's mind that the details of making a given casting are pretty adequately described to the founder by the words "made in green sand," "made in loam," etc.

Green Sand Method.—This is the common method used for ordinary miscellaneous castings. The mold in this process is made by ramming slightly moistened sand around a pattern in a wooden or iron box or "flask." The mold surface is usually smoothed over with a mineral facing, such as powdered graphite, which largely prevents the iron from penetrating the sand, thus producing a rather smooth surface. The core in strictly green sand castings is made by ramming green sand into a "core box;" but for most castings, especially pipe castings, a dry sand, or a baked mud, or a hayed spindle and baked mud core are used with the green sand exterior mold. Such castings are still called green sand castings. Fig. 1 shows the mold for a small branch. The green sand method is almost invariably used for small castings, often for rather large ones, and sometimes for very large castings of convenient shape; but the slightly damp sand is not cohesive enough to hold together and maintain its shape in deep and complicated castings.

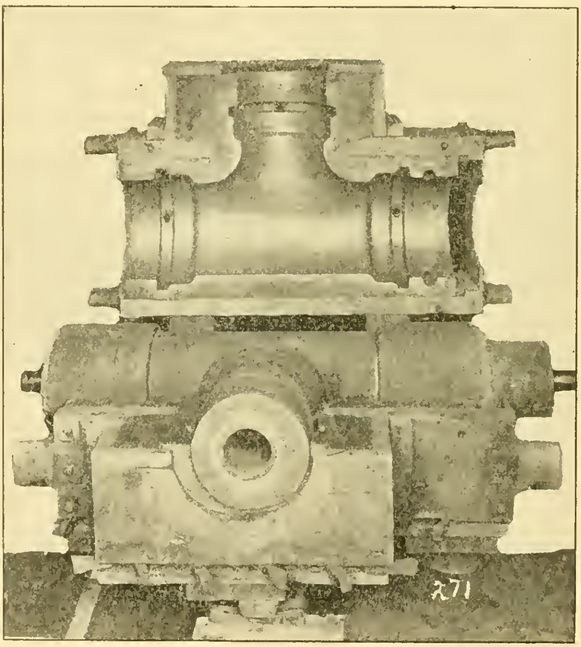
Dry Sand Method.—This method is used in moderately large and complex castings where a green sand mold would be liable to break or strain, and in general work where a more accurate shape

*Manuscript received July 18, 1898.—Secretary, Ass'n of Eng. Socs.

†The following descriptions are necessarily superficial, as molding is a science by itself.

and smoother surface are desired than are obtainable with green sand. The process of ramming the earth around the pattern is essentially the same as in the green sand method; but for the rest, there are these important differences: The earth used, at least next the pattern, is of a more cohesive nature (cohesion increased by addition of flour and clay water); the mold is rammed in an iron flask and the surface of the mold coated with a liquid blacking containing carbonaceous material, such as powdered coal and

FIG. 1.



graphite (mixed with clay water or molasses or other liquid); and the whole is baked, for perhaps twenty-four hours, in an oven of moderate temperature. The core in the dry sand method is made in dry sand, of baked mud or of baked mud over hayed spindle.

Loam Method.—Most of the largest and heaviest castings, such as are required for heavy machinery, are made in loam; also many castings that can be made without a pattern if made in loam. The loam mold is made by building up around a pattern, or otherwise, a structure of the desired shape with soft bricks, iron binding plates and mud made with clay, sand, wheat flour, clay water, etc.,

or other cohesive mixture, with some ingredient to keep it sufficiently porous. A skim coat of fine mud is put on, the surface is blackened with liquid blacking and the mold is baked in the oven, as in the dry sand method. In some cases, such as large water pipe curves, the method is cheapened by having a cast iron flask a little larger and about the shape of the object, and lining this flask with split brick and loam.

The grounds for the choice of method of molding have been very roughly indicated in the foregoing, but the method chosen for a given casting will depend on the particular circumstances, such as the smoothness desired, the fittings on hand, the number of one kind desired, etc.; and also, in a large measure, on the judgment of the founder who is making the selection. The following list gives the methods generally used in making castings for the Metropolitan Water Works. Such a list would vary somewhat for the different foundries, but the one here given is substantially correct for all:

Green sand, no core.—All caps, covers, etc.

Green sand, with green sand core.—Sleeves, 12-inch, 16-inch, 20-inch and 24-inch.

Green sand, with baked core.—All specials, 12-inch and under, except sleeves and caps above mentioned.

Dry sand, with baked core.—All straight pipes; all long (12 feet) reducers; blow-offs, 16-inch, 20-inch and 24-inch; tees, most 16 inches and larger.

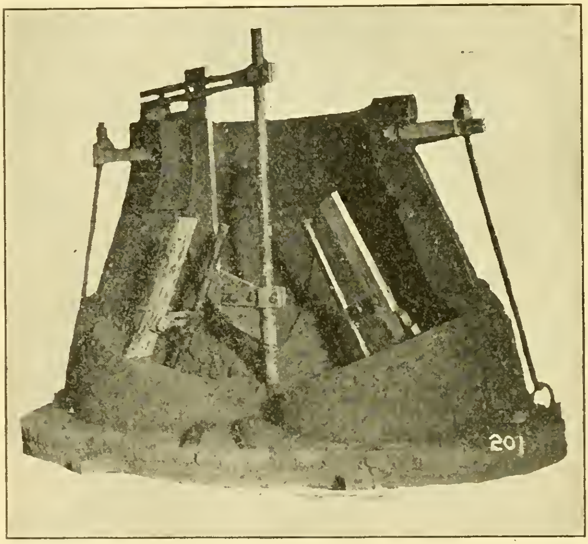
Loam.—Curves, 24-inch and larger; tees, a few of the larger; reducers, 16-inch and larger (except long ones cast in dry sand, as above noted); blow-off branches, 30-inch and larger; all manhole pipes.

Swept-up Molds in Loam.—It was stated that the loam method is used in many castings that can be made without a pattern, *if* made in loam. Perhaps the most important of such castings are those belonging to what are called, geometrically, solids of revolution. Now, all pipe castings are composed largely of one or more solids of revolution. Hence, molds for many of these (all of those mentioned above as being cast in loam) are made wholly, or mostly, without patterns, by the use of the sweep and the spindle. The spindle (this word is used to designate also the iron frame for cores) is usually only a straight, round bar of iron, three inches, more or less, in diameter, which is fixed firmly in the proposed axis of the mold, and serves as the axis of revolution for the sweep. The sweep consists of an iron collar and arm, with board of proper shape bolted to the arm, the board being furnished usually with an

iron cutting-edge. The collar is lowered over the spindle and turns on it. The sweep can hence be readily revolved around the spindle, and serves as a guide in placing the bricks and loam in the mold; it also serves to cut off the surplus loam and shape the surface of the mold.

The spindle for the curve is bent to the shape of the center line of the pipe, and the mold is built up as in the case of the simple castings, like reducers, only the position of the collar of the sweep has to be changed every six inches or so on the spindle. The result is not an exact curve, for, in order to produce an exact curve,

Fig. 2.



the collar would have to be changed continuously, but any apparent angles are smoothed over by hand by the molder. The chief errors in curves are caused by not bending the spindle properly to the axis of the pipe, and by not setting the spindle properly in its base. With reasonable care, large curves, such as 48-inch and 36-inch, can be made without error, in laying-angle, larger than that corresponding to about an inch of joint opening, and with but few errors larger than that corresponding to $\frac{1}{2}$ inch of joint opening. However, if care is not taken to test the curves, by template or otherwise, errors much larger and really troublesome will creep in. Fig. 2 shows one-half of the outside mold for a Y branch, with the sweeps and spindles, that were used in shaping the mold, in

position. The Y branch is rather a complicated swept-up casting, requiring three spindles; the core is made in four sections, which are afterward put together.

Straight Pipes.

Straight pipes were formerly made by the green sand method, and later with a baked core. They were cast on their sides, as many building columns are still cast, with the result of uneven thickness. Pipes are now cast invariably with their axis vertical, and, with the exception of a few small pipes, are cast with the heads, or bell ends, down.

The enormous use of cast iron water and gas pipes has caused the development of a highly perfected system of making molds, in which labor is reduced to a comparatively small amount. The mold is divided into a number of easily-made parts, each one of which is made by an individual, or by a gang, specially trained to make it. In short, the same specialization is applied that is universal in other factories where large numbers of one article are made.

THE MOLD.

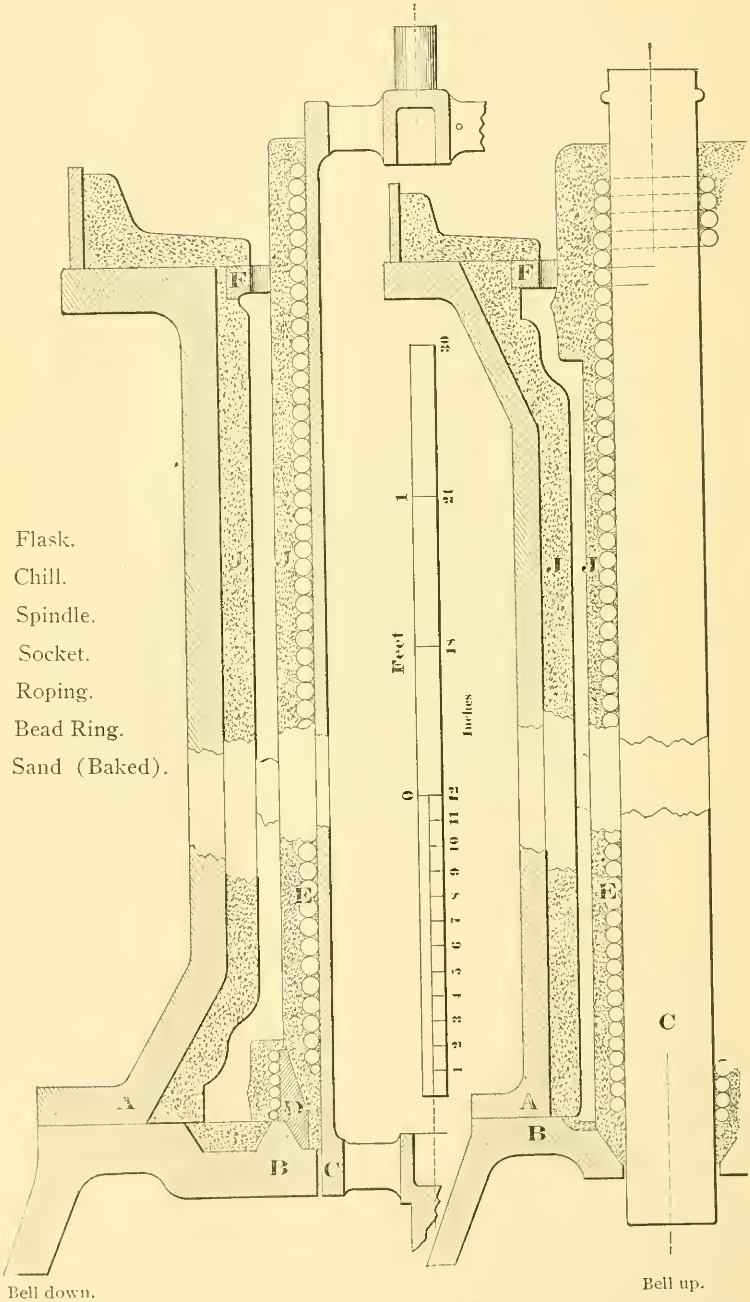
The arrangement of the mold is shown in Fig. 3. On the left is seen, in half section, the arrangement for casting bell down, and on the right the arrangement for casting bell up. A is the "flask," consisting of a cast iron casing for the mold. It is made in sections for convenience in making and handling. The flask is lined with sand by ramming around patterns. A sectional iron pattern is used (in the bell down method) to form the bell shape, and a turned cylindrical iron pattern is used to form the barrel of the pipe over. This iron pattern has to be of a diameter equal to the outside diameter of the pipe, plus double the thickness of the coat of blacking, plus the shrinkage of the pipe; and it is evident that a new or altered pattern is necessary for every noticeably different outside diameter of pipe.

The chill B (Fig. 3) is a cast iron machined ring, which is the foundation of the whole mold, and holds the parts accurately concentric. A small channel of earth under the face of the bell prevents the iron of the latter from being chilled, and thus serves to make the name "chill" a misnomer.

The spindle C is an iron cylinder fitted with a bearing at each end, and serves as the rigid frame for the core. E is the hay rope which forms the first layer of the covering for the spindle.

D is an iron ring called the "socket ring." The socket ring serves as the basis of the socket, which is made with hay and earth, as shown. A chain ring is often incorporated into the top of the

FIG. 3.



A. Flask.
B. Chill.
C. Spindle.
D. Socket.
E. Roping.
F. Bead Ring.
J. Sand (Baked).

HALF-SECTIONS OF PIPE MOLDS.

socket earth, to strengthen it against the shock of falling iron. It will be seen that the socket ring fits by a machined bevel and shoulder into the chill, and that the rest of the core fits into the socket ring.

At the top of the mold is the "bead ring" F, which forms the end of the pipe and the top half of the spigot bead. In the bead ring, on the edge next the core, are the six to a dozen semi-circular nicks through which the iron flows into the mold, and also the single nick, "riser," through which air and gases escape when they are displaced by the entering iron. The bead ring is made by pouring a semi-fluid mud, made very strong by liberal use of clay water and wheat flour, into an iron mold and baking it. An iron ring is usually incorporated into the bead ring to give it strength. The trough of sand resting on top of the flask is the "runner" into which the molten iron is poured.

CORE MAKING.

The iron spindle, hot from a pipe recently cast, is placed on two bearings and revolved by power transmitted through gearing similar to, though much rougher than, that in a metal-working lathe. First, twisted hay rope, made at the foundry of salt hay, is wound on. Then mud, or mully, made in a pug mill, and consisting of a mixture of argillaceous loam, sand and water, is applied to the hay rope. A true cylindrical shape is obtained by the lathe process, though the tool, unlike the lathe tool, is long enough to act on the whole length of the object at once. This tool, called the strike, consists of a plank with a straight edge, bound with iron, set and wedged at the proper distance from the center of the spindle. The first coat of mud brings the core to within perhaps half an inch of the final radius. The core is then baked over night, after which it receives the skim coat of a finer, more sandy material, and finally a coat of liquid blacking.

The common way of putting on this blacking, namely, by hand with a broad brush, destroys, to a large degree, the value of the smoothness of the skim coat of mud. The random arc-shaped ridges, covering the inside of the pipes, are often attributed to the tar coating. As far as my experience goes, nearly all the marks in water pipes are in the iron, not in the coating, and most of them can be attributed to the method of putting on the blacking. The ridges are not measurable by putting on a carpenter's rule, but it seems probable, in the light of our knowledge of the important effects of tubercles, that these marks do cause an appreciable loss in flow of clean pipes. They can be largely avoided—and they have been avoided in some cases—by smoothing the blacking by

the strike, in the same way as the mud surface is smoothed, though the labor and the risk of breaking the core are thereby somewhat increased. The change would probably not be discoverable in increased cost of pipes.

The core of a 48-inch pipe is made about a quarter of an inch larger at the bottom than at the top, in order to allow for the compression caused by the twelve feet of molten iron.

UNIFORM OUTSIDE VS. UNIFORM INSIDE DIAMETER, FROM THE FOUNDER'S VIEW.

To vary the inside diameter of a pipe is a very simple matter, requiring only the insertion or removal of one or more strips of brass at the ends of the strike. To vary the outside diameter, on the other hand, requires the construction of three new turned iron patterns: viz, a sectional one for the bell, a pattern for the socket and a long, turned cylinder for the barrel of the pipe; unless the founder happens to have apparatus on hand near enough to the required dimensions to pass the inspector, who, fortunately for the founder, usually has less respect for small dimensions, such as quarter inches, than the engineer is apt to have. The founder looks forward to the happy day when a constant outside diameter and uniform bell and lead-score designs shall rule throughout the pipe-using world. As far as convenience in making joints is concerned, the engineer must agree with the founder that uniform outside diameters are very desirable.

THE IRON.

The iron is melted in the ordinary cupola. Coke is generally used as fuel, and oyster shells or limestone are used as flux. The proportion of fuel to iron is, for a rough average, about one to eight by weight. A new fire is started each day, the cupola bottom being dropped at the end of the pouring. The remnants that are dropped from the cupola at the end of the pouring, containing some shot-like pieces of iron, some larger pieces of partially melted pig and a good many cinders, are run through a revolving cinder mill, which separates the iron from the cinders. The iron thus obtained, "shot iron," though containing, like cinder iron, an extra proportion of impurities, is worked into the charges in small quantities. Rejected castings also are used in the cupola after being broken up, and gates, risers and runners, of which a large weight is cast daily, are utilized in the same way. The runner of a 48-inch pipe will weigh about 500 pounds, say six per cent. of the weight of the pipe itself, and, of course, is not to be thrown away unless under compulsion.

Sometimes the founder gets too hurried about working in his scrap iron and gets more scrap still by bad castings. Scrap begets scrap, unless it is carefully used. In the modern chemical methods of mixing iron, however, the scrap iron and cinder iron are no longer considered as always undesirable, but have their proper uses in obtaining required chemical composition. Iron of a given composition is identical, whether it is obtained by the use of scrap or by the use of pig.

POURING.

The iron is tapped from the cupola into a pouring ladle holding, in straight pipe work, from three to six tons. If the iron is thought to be too hot,—*i.e.*, hot enough to injure the mold,—it is either allowed to stand until cool enough, or cooled down quickly by the addition of scrap iron or pig. The ladle is then skimmed of dross, and a little earth is thrown in on the iron near the nose of the ladle, forming a cake which acts as a dam to keep back newly-formed dross.

Two methods of pouring are used for large pipes. One is to pour the iron directly into the runner and allow it to fall to the bottom of the mold; the other is to begin pouring through what is called the main gate, or side runner, a sand-lined passage about $1\frac{1}{4}$ inches in diameter, leading from the top of the flask to an opening into the bell cavity, in order to prevent the iron from falling 12 feet or more on to the shoulder of the socket, which obviously has to stand the shock of the iron so falling in the method first described. By the second method, iron is poured through the main gate until the metal stands above the socket, when the main gate is plugged and pouring goes on as in the first method. Advocates of the simpler first method claim that, by the method of pouring at first from the bottom, a cool scum is formed on the iron which has come slowly in through the main gate, so that the iron afterwards coming in at the top does not unite perfectly with the former, causing a partial cold shut just above the socket. The two methods are apparently used with equal success, and the simpler method of pouring wholly from the top is the one most commonly used.

The principal point to observe in pouring is to keep the runner full, so that the scum will float in the runner and not be allowed to get through the gates.

VENTING MOLDS.

When red-hot iron comes in contact with a mold a large volume of steam and other gases is formed, and must have means of rapid egress. Air and other gases, displaced from the mold cavity

by the iron, escape largely by the "risers," or open holes similar to gates, left in the top of the mold as passages for escaping gases. But gases are formed in the material of the mold, and in pipe molds egress is provided for by having many holes in the flask and in the spindle. The gases burn with a blue flame at these vent holes during and after pouring.

As the escape of gases must be provided for, the founder is careful not to use molding earth of too compact a texture.

PULLING THE SPINDLES.

After the pipe has been poured, the mold, with the contained pipe, is allowed to stand for perhaps twenty minutes. Then the spindle is hoisted out. In this connection the use of the hay rope in the core is best explained. The hay rope is sufficiently firm to hold the metal in place until it hardens, but it is sufficiently yielding to allow the pipe to shrink as much as it will in cooling to a self-supporting state, without binding the spindle immovably in place. If no cushion of hay were put between earth and spindle, the pipe would either shrink immovably onto the spindle or perhaps burst. Even with the hay rope a pipe is occasionally allowed to cool too long before the attempt is made to withdraw the spindle, with the result that the spindle is bound in inextricably for the time. In such cases, after the pipe is cool, the hay and earth are laboriously cut out with a long, thin saw.

TURNING OUT THE PIPES.

The pipes are usually allowed to stand in the flask until fairly cool, often over night. Small pipes, however, 16-inch and under, are often turned out while still red, which perhaps may cause them injury by sudden cooling. At any rate, enough of them crack in handling to give credence to such a theory, in the absence of comparative records of pipes turned out hot and pipes turned out cold.

CLEANING THE PIPES.

The pipes come from the casting pit with iron socket ring in bell, all the core earth inside the barrel (the hay has all been burned out in a grand conflagration occurring when the spindle is removed) and with gates and fins projecting. It is a day's work for about four men to clean away the dirt and chip off the fins and gates from, say, fifteen 48-inch pipes. If the pipes are scabbed, it will take much more labor.

INSPECTION.

After the castings are cleaned the inspector goes over them and decides which are all right, which will be acceptable if their spigot ends are cut off and which are too imperfect for acceptance.

The inspectors are usually hard-headed, practical men, and a large proportion of them have grown up in foundry localities, have been employed in foundries previous to becoming inspectors and hence know the imperfections to which castings are liable, though their knowledge of metallurgical chemistry is slight. As far as the writer observed, the inspectors are absolutely fearless and unswerving in carrying out their convictions or their instructions.

The writer was told by a founder that the causes leading to imperfections in castings have been numbered above a hundred. The practical imperfections in pipes, however, can be reduced to a smaller number:

1. Mistakes in dimensions, due to inaccurate measurements of patterns, wrong setting of strikes for cores (losing a brass, for example), etc. These are rare after an order is well started.

2. Too small diameter, due to abnormally high shrinkage. This occurs rarely, and only with large pipes.

3. Scabs. A scab is caused by the coming out of a piece of the mold. An irregular excrescence on the pipe is thereby caused. But this does no harm in itself. The excrescence may be chipped off, unless so large as to require too much labor. The objection to scabs consists in the uncertainty as to what has become of the dirt which broke from the mold. It has floated off up into the pipe, and may be lodged under a thin skin of iron somewhere in the barrel of the pipe. If it is evident that the dislodged earth has floated to the top of the pipe, then the top of the pipe may be cut off and the rest of the pipe considered good. If it is uncertain where the dirt went to, then it is the part of prudence to reject the pipe, if the scab is of considerable size.

4. Mold-cut. A mold-cut is caused by the iron penetrating the mold and partly including within itself a piece of mold. The dirt does not float away, but remains partly in sight. The mold-cut, if of considerable size, is fatal.

5. Socket-cut. This is a mold-cut in the socket, caused by the iron getting between the earth and the metal ring. It is usually fatal.

6. Dirt fallen in by accident when the runner is made. There is usually a little of this, occasionally enough to show, and sometimes probably enough to cause unseen damage, because, unlike the scab, this dirt leaves no tell-tale excrescence to show its presence.

7. Core-swells and core-strains. Sometimes the core is not firm enough and becomes distorted. This shows in the inside of the pipe and sometimes causes rejection. A skilled inspector told

the writer that a more important and more insiduous injury than uneven surfaces was sometimes caused by core-strains. A core might continue to give slowly after a crust had been formed all around the pipe and the gates had become too hard to admit more iron. The result was that the molten iron settled down, leaving invisible cavities between the shells at the tops. The writer has seen hidden cavities 4 inches square and $\frac{3}{4}$ inch deep found in the tops of 48-inch pipes. They occurred at the gates, and were called "gate-shrinks." Whether such cavities are due to core-strains, or to simple shrinkage, or to both causes, it is obvious that the gates should be kept open to supply iron until danger of cavities is past. At one foundry it was the practice to keep the gates from freezing, for perhaps one minute after pouring, by the use of a poker.

8. Scale. Occasionally founders are troubled by a continuous run of scale, the cause of which the writer has never heard explained. A thin substance appears in blotches, sometimes a yard square and perhaps one-sixteenth of an inch thick, on the inside of the pipe. It appears to be partly of metal, adheres strongly, though not immovably, to the pipes, and, when removed, usually leaves a little shoulder where it fades into the clear iron.

9. Imperfect spigots. Imperfect spigots may be due to several things, such as shrink-holes, dirt, dross, check cracks, etc. The top end of a pipe is the catch-all for the dirt, dross, etc., that may be in the iron, and for dirt from the scabs, etc., for all these impurities are lighter than iron and tend to rise to the top. The remedy for it all is to cut off the imperfect part, and, in castings of which it is important to have the ends clean for facing, etc., it is customary to cast on an extra top, or "shrink-head," so called, to collect all the impurities. This shrink-head is then cut off, leaving a clean casting. Imperfect bead ends are by far the most common defect in pipes. The cut pipe is objectionable for several reasons: (1st) its length is uncertain, so that it cannot be calculated on; (2d) it is shorter than standard and increases the number of lead joints in pipe lines; (3d) the wrought iron bead, which replaces the cast iron one, is apt to come off, though this is unlikely, if a *rectangular* channel is cut around the pipe for the bead ring to rest in.

10. Shrinkage cracks. These are comparatively rare, and usually short. They are sometimes found around the bell, sometimes at the spigot end.

11. Underweight and overweight. If a pipe is below a certain fixed minimum weight the inspector cannot accept it. If it

is above a certain weight the inspector has no objections to taking it, but the founder will then be giving away some iron. Hence, sometimes the founder keeps the overweight pipes for stock.

12. "Out of round." Occasionally a flask will so behave as to distort the pipe, presumably changing its shape after the spindle is removed. The reason is not clear; the fact is stated on the assertion of founders.

13. Uneven thickness. This may be caused by the misplacing of the core, in which case it will show at the ends, or by failure to pull the pattern in a straight line while ramming the mold. Uneven thickness may be discovered by caliper measurements, but most easily by watching the rolling of the pipe on smooth, level skids. The heavy side will go down rapidly and tend to stay down. This is a rare defect in pipes cast vertically. All know its frequency with horizontal core-castings.

14. Unsuitable iron. The inspector judges whether the iron is soft enough to cut and drill, not cold-short nor red-short, and generally clean. Rarely he rejects ladings for too hard or too brittle iron, supposed cold- or red-shortness or general dirtiness; but, as a rule, any perfectly-formed casting passes muster. The methods used in the attempt to judge of suitability of iron will be described presently.

15. Leaking or bursting in press. Sometimes a pipe will develop leaks in press, usually near the spigot, and caused by dirt, dross, etc.; and less often a pipe will actually burst. Twenty-two out of 14,500 pipes, the records of which the writer studied, burst in press, and there is no telling whether some of these had not been previously injured in handling.

16. Cracked in handling. This requires no explanation. Many pipes are found cracked after receipt by the purchasers.

Some figures on rejected, burst, cut and split pipes are given in Tables I and II.

The inspector goes over each pipe carefully, pecking it strongly all around the spigot end, inside and out, and at any other doubtful points, measuring the thickness at the ends with calipers, rolling the pipe for uneven thickness, and judging whether the iron can be drilled and cut. Special castings are examined with equal care, and all anchors are carefully headed over to prevent leaks. In fact, the inspector, backed by the modern cast iron specifications, holds the founder up to the highest pitch in workmanship, which he is able to reach by accepted methods and apparatus.

COATING.

In this connection the common method of coating pipes* will be described. Further on the question will be discussed somewhat, in the light of a number of experiments tried for the Metropolitan Water Works.

The inspector having passed judgment on the pipes, they are rolled along down to the coating apparatus. The apparatus consists of a number of ovens, with iron cars, on which the pipes are rolled into the oven and on which they stand during heating, a vat or tank for the coating compound, a crane for hoisting the pipes in and out of the vat, and various brushes, scrapers and mops for brushing out dirt and removing surplus coating material. The coating material is crude gas tar with sometimes some dead oil of tar added. The pipes are given a fairly good brushing before being put in the oven. The oven is merely an enlarged chimney flue, for all the smoke and gases of combustion pass in at one part and out at another, so that a light, but visible deposit of soot is made on the pipes, which is not brushed off. The old-fashioned ovens have simply a square hole through the floor of the oven connecting it with the fire, so that the hot gases, and occasionally flame, act principally upon one portion of the pipe, heating that portion very hot before materially affecting the other portions. The newer ovens are fitted with an arched bottom, with bricks left out at intervals all along the pipe, this arrangement causing a more uniform temperature. The pipe is left in the oven until the attendants think (no thermometer is used) it is heated to about the correct temperature (48-inch pipes are left in about 20 minutes); then it is put in the tar to stay from a moment to 10 minutes, according to the condition of the work about the vat. On being removed from the vat, the pipe is allowed to drain over the vat, and the drainage is aided by scraping the invert with a segmental hoe, made to fit, or at least to be of smaller radius than the pipe. The pipe is then lifted out onto the skids and the coating smoothed up further—surplus tar removed and thin places reinforced—by a brush or a mop. The brush is better because the mop leaves part of itself behind on each pipe. The coating becomes hard in from ½ to 2 hours, according to conditions.

WEIGHING.

The pipes are now passed over a set of platform scales and weighed. The inspector witnesses the weighing and also the

*Gas pipes, of course, are not coated; moreover, a few cities do not have their water pipes coated, as their water does not act much on cast iron.

painting of the weight, class and number on the inside of the pipe, in white lead.

PROVING.

The next step in the life of a pipe is to be proved,—*i.e.*, subjected to hydraulic pressure. The pipe is placed between two heavy discs, one of which is stationary, and the other of which is attached to the piston of a hydraulic cylinder. Proper gaskets are placed between the ends of the pipe and the disc, and the hydraulic press squeezes the pipe and gaskets firmly between the discs, thus closing the ends of the pipe. Water at low pressure is then let into the pipe through an orifice in one of the discs, and the air in the pipe is forced out through another orifice at the top of the pipe. It is important to have practically all the air out of the pipe, as the expansive force of the air is liable to throw fragments of pipe in case of bursting. If there is no air present the bursting of a pipe is very quiet. When the pipe is filled with water, the air valve is shut and water at high pressure is turned on. The high pressure shuts off the low pressure by a check-valve, and the pressure is run up usually to 300 pounds, and held until the inspector is satisfied. The inspector makes it a point to hit the pipe several blows in different places, while the pressure is on, to aid in the development of incipient cracks.

As already noted, the number of pipes burst in press is very small. The reason is not far to seek. The pipe of the M. W. W. schedule, which (barring the 54-inch and 60-inch pipes) would be subjected to the greatest tension per square inch, at 300 pounds' pressure, is the 48-inch, class A, having a thickness of 1.15 inch. The theoretical tensile stress in this pipe, at 300 pounds, would be $\frac{300 \times 48}{2 \times 1.15} = 6260$ pounds per square inch. Now it is very weak iron that will not stand 15,000 pounds per square inch, which would give a safety factor of 2.4 if the iron were homogeneous. The fracture in press should probably be ascribed to defects such as shrinkage or other cracks existing before proving. It is conceivable, however, that an occasional pipe may be sufficiently hidebound to cause its own fracture in press.

When the pipe has successfully borne the hydraulic test, the inspector allows his initial to be painted in the pipe. He is then through with the pipe, and it is placed ready for shipment.

The foundries which the writer has seen are so laid out that the course of a pipe from process to process is on a gentle slope. This makes handling easy.

Tests for the Iron.

There is one important matter in the inspection of cast iron pipes which is generally thought to need more reliable judgment than the practical inspector is able to pass by the aid merely of his sense of sight, of touch and of hearing; and that is, the matter of suitability of the iron in the pipes. Perfectly-formed pipes can be made of iron of widely varying grades, may all pass the inspector, and perhaps all give fair satisfaction; but some of the iron will be more suitable than the other, and it seems reasonable that some attempt should be made to get the better iron. A description of the tests used by the Metropolitan Water Board will be prefaced by a simple *résumé* of the subject of practical testing. These properties of cast iron which the engineer must chiefly scrutinize may be roughly named as follows:

Strength.

Hardness.

Durability.

Strength is here used in a very broad sense to include resistance to injury against single and repeated, gradually-applied loads and shocks. The ability to bear shock involves the elastic deformation of the material as well as the ability to bear stress, but all is included in this rough heading—strength.

In hardness is included the capability of being cut, drilled, filed, etc. Durability is used with reference to chemical agents, durability under repeated stress being included in strength.

These properties are desired in varying degree according to the purpose for which the iron is to be used. For machinery castings ease of machining is often treated as the prime requisite. For pipe castings, strength and capability of being cut and drilled are usually considered of paramount importance. Some engineers have preferred hard iron because of its durability against chemical agents existing in earth and water, but the matter of durability is usually neglected.

It is too commonly thought that iron is divided into two classes,—viz., good iron, having all desirable properties, and bad iron, deficient in these properties. Every kind of iron has its sphere of usefulness, and no iron can be best for many different purposes.

The problem of the founder in supplying iron of desired properties is well summed up in the following words on choice of iron for a casting: "For most purposes is needed an iron which (1) shows a gray fracture, (2) forms no finery scum, (3) is easily worked by chisel and file, (4) fills the mold even to the thinnest

sections, (5) chills with a smooth surface, (6) has moderate strength, (7) is free from blow-holes, (8) shrinks but little. These conditions are well filled by an iron containing, after melting and casting,

Carbon,	3.5 per cent.
Silicon,	1.5 to 2 per cent.
Phosphorus,	not over 0.7 per cent.
Manganese,	as little as may be (unless chill is desired).
Sulphur,	a trace.

"When such a mixture has been obtained variations may be made. For large castings, lower the silicon; for small castings, increase the silicon. If shrinkage is to be avoided, lower the manganese. If much strength is required, lower the carbon, silicon, manganese, and avoid phosphorus. If resistance to chemical action is required, make manganese as high as brittleness will allow."*

It is evident that the desired properties tend to conflict with each other. Thus, strength conflicts with the *highest* chemical durability, though strong, close irons are more durable than weak, open irons.

I. DIRECT TESTS.

The direct method of determining the ability of the metal in a casting to be tooled is to *try* it by chisel and file and pointed hammer. The direct method of testing strength is to subject the casting to stress. At about the middle of this century the practice prevailed somewhat of testing, to breaking, one cast iron girder picked at random from a lot, in order to judge of the suitability of the remaining girders.† This is decidedly the most direct test possible, though it still is not a test of the very castings to be used. The ordinary method for pipes is of course to test by hydraulic pressure, but *not* to breaking, the test pressure being kept safely below the breaking pressure, as fully described on page 223.

Almost all tests for strength are made with single, gradually-applied loads, and the assumption is then consciously or unconsciously made, that the iron which will best bear such tests will also bear repeated loads and shocks incident to actual use. The assumption seems a reasonable one when both strength and stretch are considered in testing; but it was not a true one when strength

*Professor R. H. Richards, Mass. Inst. Technology. "Notes on Metallurgy of Iron."

†See Report of British Commissioners on Iron for R. R. Structures, 1849, p. 297.

alone was used,* and it is not necessarily a true one in either case. Who can say positively, for example, that the high per cent. of Foundry "Z" 16-inch and 20-inch split pipes (see lines 50 and 51 of Table 1) is not due to a weakness of the iron against single or repeated shocks, though it is very strong and elastic under gradual loading?

Impact tests have been used to determine the ability of iron to bear shocks, and perhaps such tests would still be of advantage, as it is shock that breaks most pipes.

There can of course be no direct test except use for the chemical durability of iron under circumstances existing in use.

2. INDIRECT TESTS.

(a) *Appearance.* The simplest and most common indirect test is examination of fractured section, where "fins" and "gates" have been broken off. The efficiency of this method depends wholly on the experience and memory of the observer, and this experience depends on direct tests previously made. Iron of a certain appearance having been found satisfactory in the past, by practical tests and use, it is assumed that all iron of the same appearance has the same good qualities.

The most striking peculiarities of texture are quickly learned. Thus, fine, gray texture is soon associated with strength, coarse crystallization and much graphitic carbon with weakness, and white color with hardness and brittleness. The closer distinctions are more difficult to make and more uncertain.

(b) *Test Bars.* The first conception of a test bar was doubtless that of a cheap, easily-tested *sample,* as nearly identical in properties with the larger casting with which it was cast as are samples of tea or wine with the larger quantities of those articles from which the samples are taken. Hence, testing the specimen was considered equivalent to testing the casting itself. As early as 1849, however, experts realized the difficulty of getting true samples of cast iron. A British commission, of which Captain Henry James and Eaton Hodgkinson were members, reported,† "The strength of a bar 1 inch square should not be taken as the unit for calculating the strength of a larger casting of similar metal, although the practice of doing so has been a prevalent one; for it appears that the crystals in the portion of the bar which cools first

*High strength alone, without high stretch, is often found with very brittle iron. The old tensile tests did not furnish any safeguard against brittleness, as stretch was not observed.

†Report of British Commissioners on Iron for R. R. Structures, 1849, p. xv. See also p. 251.

are small and close, whilst the central portion of bars 2 inches square and 3 inches square is composed of comparatively large crystals, and bars of 3 inches square, planed down on all sides alike to $\frac{3}{4}$ inch square, are found to be very weak both in transverse and crushing pressure. Hence it appears desirable, in seeking for a unit for the strength of iron of which a large casting is to be made, that the bar used should equal in thickness the thickest part of the proposed casting."

This lack of uniformity in castings poured from the same "bath," and the same lack of uniformity in different parts of the same casting have long been well recognized, and assigned to influence of *rate of cooling* on the complex crystalline material called cast iron. The effect is almost invariably evident in a fractured surface of cast iron, the most pronounced case being that of chilled castings, in which the chilled portions are white iron, while the remaining portions are often ordinary-looking gray iron. In a recent work* on iron these words may be found: "Slow cooling, in large, thick castings, tends to increase precipitation of graphite, making very soft castings. Quick cooling against a chill iron surface, and less so in a very small casting, tends to high combined carbon and great hardness." And again, "The effect of size in a casting is to retard the rate of cooling, if large, and accelerate it, if small; the quicker a metal chills, the finer the graphite will be." This effect of size of casting is brought out, sometimes strikingly, by a comparison of a fractured section of heavy pipe with the section of a test bar cast from the same "bath." In many cases no points of resemblance are apparent, and in fact there are no points of resemblance in physical properties. The bars cut from pipes (see lines 9, 10, 21, 22, 32, 33 of Table I) show how different is the iron in the pipes from that in the test bars.

Notwithstanding these facts, the test bar of constant size has been used for many years, and has usually been considered as a fair sample of iron, whether castings are large or small.

Test Bars as Quasi-Direct Tests. When the bar is of such thickness† relatively to the casting that its rate of cooling, and consequently its texture, approaches closely to that of the casting, the bar would seem to furnish a rough direct test.

Test Bars as Wholly Indirect Tests. To Mr. W. J. Keep, of Detroit, Mich., Mem. Am. Inst. Min. E., is perhaps due the idea of using test bars as wholly indirect indications of the quality of

---

*Prof. R. H. Richards, Mass. Inst. of Technology. "Notes on Metallurgy of Iron."

†See pp. 235-6, also 242-3.

iron. Mr. Keep has advocated a system* of "relative" tests, including transverse tests (under both gradual loading and impact), and tests of fluidity, shrinkage and chill. In Mr. Keep's system, the tests are used, not as direct measures of the strength or elasticity of irons, but as a means of comparison of irons, a sort of mechanical analysis. Mr. Keep's system was designed to meet the need of founders for a cheap, quick way of determining how the iron from the cupola varied from day to day, and how to modify the charging in order to maintain desired properties. Mr. Keep has used the system very successfully in the conduct of the Michigan Stove Works.

The use of the test bar as an indirect test, carried to the ultimate extent, may be illustrated by the following supposed case: From a certain bath of cast iron some castings of a certain thickness are made, and some test bars. The bars are tested and give certain results; the castings are put to use and are found of satisfactory strength, workableness and durability. More castings like the first are now desired, and the engineer specifies that similar test bars of the new iron shall be able to stand the same tests as did the former bars, believing that he is sure to get as suitable iron as was obtained before. This action rests on the assumption that the new castings are sure to be like the old ones, provided the new test bars are like the old ones, though, in either case, the metal in the bars is not like that in the castings, owing to different cooling. The safety of the assumption depends on the number and character of the tests used for the test bars. Mr. Keep uses a number of tests as above noted. Any single test is unsatisfactory. For example, the tensile test of 1 x 1-inch bars, which has been used so much, does not furnish any satisfactory identification of iron. Irons of widely different characters can have the same tensile strength in a 1 x 1-inch bar. If the stretch also were measured the identification would be closer; but it is difficult to measure the stretch of a tensile specimen, and it is never done in ordinary tests.

Transverse Tests.—System used in the Metropolitan Water Works. The transverse test of a specimen is the cheapest and easiest test to make and is becoming very common. The only example known to the writer of the methodical application† of the transverse test on a large scale is the system carried on in the Metropolitan Water Works under the direction of our President, Mr. Dexter Brackett, M. Am. Soc. C. E. This system will now be

---

*See *Iron Age*, Vol. XLI, and elsewhere.

†By *purchasers* of castings.

described in some detail, and some conclusions stated which experience* with the system have suggested to the writer.

The specimen bars are 2 inches by 1 inch in section and 26 inches long, and are tested with a span of 24 inches, flatwise,—*i.e.*, in the weakest position. Specifications require bars so tested to stand 1900 pounds as a daily average from a cupola, with a deflection averaging at least 0.3 inch. Pipes are sometimes rejected altogether for weak iron, more often accepted at a reduced price for use at a lower pressure.

Method of Making Test Bars. The founders have been practically unrestricted in the matter of method of making the bars, the only stipulations being that the bars should be cast with a true specimen of the iron which went into the pipes; should be cast reasonably near to size, and should not be annealed. Consequently the bars have been cast by various methods. Some have been cast in dry sand with wooden flasks, some in dry sand with iron flasks and some in green sand (dry sand bars are cast on end, green sand bars flatwise); still others have been cast in dry sand and gated together in pairs. Most of the molds were faced so as to make a moderately smooth surface, but some bars have been cast in unfaced green sand and have had a rough sandpaper-like surface. One lot of bars was cast of extra large size and planed down to 2 inches by 1 inch, though these bars were not considered as test pieces.

Method of Obtaining Representative Iron in Bars. The bars were poured at such times and in such manner as would give fair samples of the iron, though the number of bars was of course limited. An actual instance will best explain: With a daily lading of fourteen 48-inch pipes there were cast four bars as follows: The first bar with the first pipe, the second bar with the fifth pipe, the third bar with the tenth pipe and the fourth bar with the fourteenth pipe; with twenty-seven 16-inch pipes there were cast three bars,—one with each of the first, fourth and seventh ladlefuls, only about eight ladlefuls being required to pour all the twenty-seven pipes; and bars for other work were poured at intervals according to the same idea, though never less than two bars were intended to be cast to represent any single heat.

The idea was to get the average quality of the iron for each day's cast from a given cupola, and if this average was unsatisfac-

*The writer owes it to the completeness of this record to state that this experience consisted of the testing of about 2000 bars, in a period of eight months, at two foundries, and daily observations of molding and casting many of the bars.

tory, the whole day's cast from that cupola was considered weak. It was not known what pipes were cast with each bar; moreover, not all pipes were cast with any bar; and, finally, the indications of a single bar were surely too uncertain to condemn castings by. This method, then, assumed that the iron from a given cupola ran fairly uniform during a day's heat; for, if some good and some bad iron was cast, there was no way of weeding out the castings made with the poor iron. Such an assumption would usually be fair, but it is not necessarily so. At one foundry, for example, a mixture containing 15 per cent. or more steel was cast from one cupola, for special work, at the beginning of the heat, while an hour later no evidence of steel was discernible in the iron. Moreover, large accidental variations in the charging of cupolas occur, especially when the charging is entrusted to ignorant negroes. On one occasion a marked difference each day in the character of the first test bar from a certain cupola led to the discovery that the charger was using no scrap for the first part against four-tenths scrap for the rest of the heat. It would take a large number of bars to justify in the least a rejection of iron cast in parts of a heat.

The details of the method of obtaining the iron for a bar are also worthy of attention. In any case a small hand-ladle is necessary for so small a casting. Three methods of getting the iron into the small ladle are available:

1. The iron may be poured from the large ladle into the hand-ladle. Foundrymen object to this method on the ground that the iron gets too cool by being poured through the air so many times; and also because there is considerable danger that the man who holds the small ladle may get burned by spilled iron. Either objection seems sufficient to condemn the method.

2. The iron may be dipped from the large ladle with the hand-ladle. This is a very good way, though rather hard on the hand-ladle.

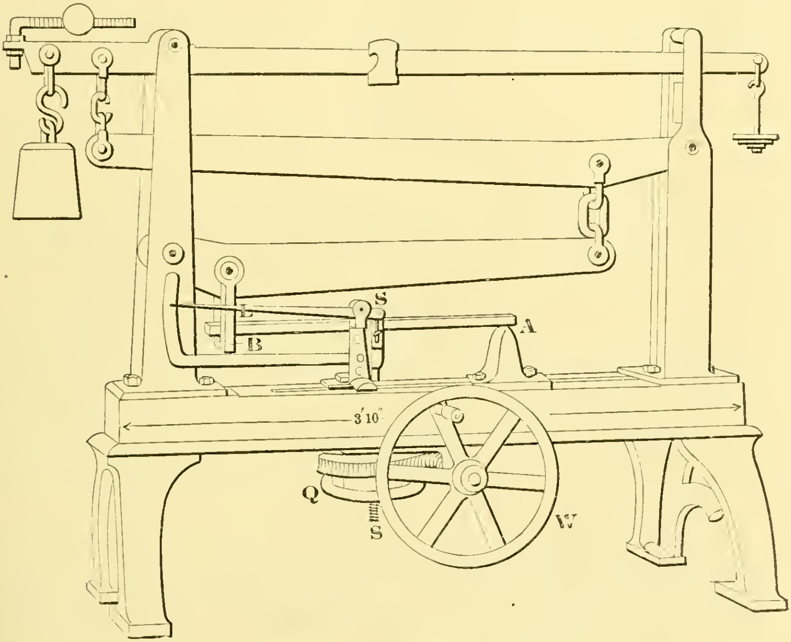
3. The iron may be caught by holding the hand-ladle under the cupola spout, over the large ladle. This was the method almost invariably used. A palpable objection to it arises when scrap or pig iron is added to the large ladle to cool the iron, thereby making its composition different from that of iron taken directly from the spout. As the cooling iron rarely exceeds 200 pounds in 8000 pounds, and is of approximately the same composition as the cupola iron, the difference is probably negligible. The method of pouring is generally considered by the founders to be important, bars poured with hot iron being usually considered strongest.*

*See paper by Thos. D. West, *American Machinist*, August 30, 1894, p. 11.

Method of Testing the Bars. The bars were tested as beams of 2 inches width, 1 inch depth and 24 inches span, supported at the ends and loaded at the middle. The load was applied gradually. The center deflection of the bars, at certain loads and at breaking, was recorded.

Testing Machines. The machines used for the tests were of the type made by Riehlé Bros., Philadelphia, for the purpose. An illustration is given in Fig. 4. The test bar rests at one end on a rigid support A, and at the other end in a rectangular loop, B, attached to a set of scale beams. The scales therefore receive only

FIG. 4.



one-half of the center load, but the scale beam is graduated to record the whole center load.

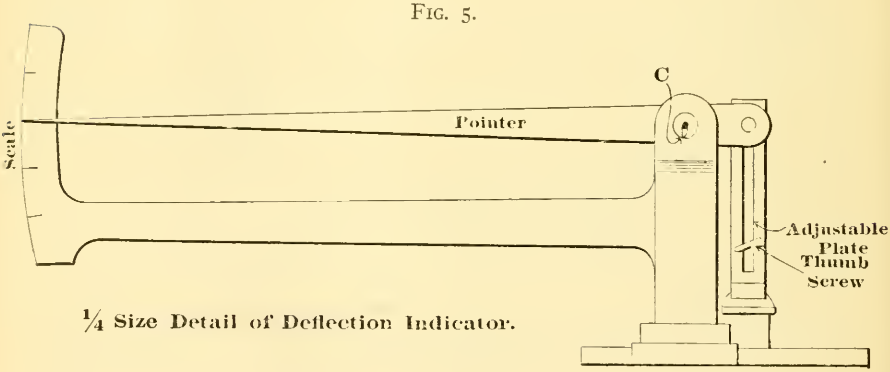
The load is applied by a screw, SS, which is spread at the top into a rectangular loop, through which the bar lies during testing. Power may be applied by the quick motion wheel, Q, which is fastened directly to the nut that works on SS, or by the slow motion wheel, W, which is geared to the nut by a worm. One turn of W causes a deflection in the bar of 0.0027 inch; 74 turns of W cause one turn of Q and a deflection of 0.20 inch in the bar.

The deflection is indicated by a multiplying lever, L, the

short arm of which is attached to the rectangular loop of the screw SS. Fig. 5 shows the details of the lever.

The common way of testing was as follows: A load of 10 pounds was first applied to the bar, then the deflection pointer was set at zero, then a load of about 1500 pounds was put on by quick motion, and finally the slow motion wheel was used up to the point of breaking. Deflections at loads of 1900, 2100 and 2300 pounds and at breaking were recorded, a short pause in applying the load being usually made to allow the deflections taken before breaking to be recorded. Some of the bars were tested by using the slow motion from 0 to breaking, making no stops when intermediate deflections were taken. As far as could be judged by comparison, the two methods give practically the same results, although the slow motion method has certain obvious theoretical advantages.

Fig. 5.



¼ Size Detail of Deflection Indicator.

The total time of applying the load to a bar was about $1\frac{1}{2}$ to 2 minutes. It required only a little longer for the slow motion than for the quick motion method, because the latter involved a short pause at about 1500 pounds load for throwing the slow motion into gear, which partly offset the gain in time up to this point.

Precision of Testing. The weighed breaking loads are probably, in most cases, within 15 pounds of the *actual maximum load* which the bars sustained during testing. (This does not mean that different loads would not have been obtained if a different speed had been used.) The constantly varying load had to be kept balanced on the scales by moving the sliding weight along the scale beam, and adding necessary weights to the scale pan, and of course these operations were sure to entail some error. Another

error was caused by the sliding weight being moved by the shock at fracture. Occasionally a bar would break under 1500 or 1600 pounds, before weighing was begun, and its breaking load could only be estimated.

The deflections were liable to several more or less determinate errors:

(a) Any local compression of the bar at the knife edges caused a corresponding *positive* error in the deflection. This local compression was usually small, but was very noticeable with rough, sandy bars. In the case of rough bars the error could be largely eliminated by applying three or four hundred pounds before testing, in order to crush the sand at the bearing points.

(b) The compression of the scale bearings and the bending of the levers in the scale system caused an error which was observed in two cases to be about + 0.003 inch.

(c) Any shifting of the deflection pointer in the circular bearing (c, Fig. 5) caused an error in the indicated deflection. This error was usually small, but probably reached 0.01 inch in some of the deflections taken after the bar had broken, as the shock of fracture shifted the pointer on its bearing. The error was as likely to be negative as positive. A slight alteration in the bearing, making the surface flat instead of circular, would remove nearly the whole of the error from this source.

(d) The whole backlash of the power screw and nut occurred as a positive error in final deflections observed *after* bars had broken. The backlash error could have been eliminated, and was eliminated in some cases, by watching the pointer and taking the deflection *at* breaking. Moreover, the correction to be applied to observations taken after breaking could be determined approximately by comparing the final deflection observed *at* breaking with the deflection observed after breaking. On one machine this backlash correction was about 0.005 inch and on another about 0.012 inch, the correction of course to be subtracted.

On the whole, the recorded deflections were probably rarely more than 0.01 inch in error, although warped bars and rough bars were liable to greater errors.

It is evident that the errors in testing are all negligible, considering the roughness of the whole test bar method. The errors are considered here in order that it may be seen that they *are* negligible.

It must be remembered, however, that, although the results of the tests give correctly enough the *actual* loads and deflections obtained by the method and speed of loading used, these results

are not strictly comparable with results obtained by other methods and with other speeds of loading.

Tables I and II give respectively the detailed and the collective summary of most of the transverse tests made for the Metropolitan Water Works from April, 1896, to February, 1897.

Discussion of the Metropolitan Water Works' Tests. The writer is confident that the iron at any of the pipe foundries would ordinarily have fulfilled the requirements of 1900 pounds load and 0.30 inch deflection in 2 x 1 x 24-inch bars. The effect of enforcing the requirements was to cause the founders to try to prevent even occasional lapses. Any iron meeting these requirements was accepted, but the founders came to take pleasure in producing bars of high strength, presumably without increasing the cost of the iron unnecessarily, sometimes by cheapening it. To the founder of the old school, at least, *good* iron means an open grade of iron, having low shrinkage and easily machined. Ordinary grades of such iron give weak test bars, however, and in one case, at least, it was found advisable to mix some scrap with the good iron to produce closer and stronger iron, thus making the iron cheaper. The foreman thought it most unwise for the engineers to choose strong, cheap iron in preference to good and more expensive iron. Moreover, the fear was expressed that the tendency to increase the strength (in the bars) and closeness of the iron was being carried too far.

The writer knows of one case where the requirements did cause some trouble to the founders. In a certain shop of one foundry were made all the green sand castings, including Metropolitan Water Works' small specials, and also a few large loam castings. The castings were mostly small and many of them required machining; hence it was desired to keep the iron soft. The attempt was apparently made to keep the iron just above 1900 pounds, but it too often went below; hence the iron for Metropolitan Water Works' specials was either brought in from some other shop, or the first part of the heat was charged specially for Metropolitan Water Works' castings.

There seems no reason to suppose that the requirements mentioned were too high, at least for castings about ½ inch or more thick. For thinner pipes, since the more rapid cooling makes the iron closer, there is room for some difference of opinion.* The importance of specifying deflection, as well as strength, is shown

*The Howard Harrison Iron Co. specifies 1800 lbs. with 0.30 inch deflection for 12-inch and smaller pipes (the weakness presumably to be due to openness, not to cold shortness, etc.), and 2000—0.35 for 14-inch and larger.

by a test made by the writer of a bar of white "shot" iron. This bar stood 2000 pounds, and, on strength alone, would be considered good. The deflection, however, was only 0.21 inch. The white iron was about as different from ordinary pipe iron as iron can be from iron. But the question immediately arises whether 2000 or 2100 should not be required, or whether a maximum limit also should be made. Such questions require a more careful study of the subject.

Pipes from about $\frac{1}{2}$ to 1 inch in thickness seem of about the same texture as corresponding 2 x 1-inch bars; hence it would seem that the tests of the bars would show, as far as transverse tests indicate anything, approximately the character of the iron in such pipes. In this connection it is pertinent to consider what transverse tests do show. The question is too complicated for complete discussion here, but the following statements can be made with some assurance:

1. The transverse strength of a cast iron beam tends to increase (a) with the tensile* strength of the iron, (b) with the stretch limit of the outside layer.

2. The deflection of a cast iron beam increases with the stretch limit of the outside layer.

3. The ultimate strength of rectangular cast iron beams is roughly twice as much as would be obtained by the ordinary† theory expressing the relations between transverse strength of beams and tensile strength per unit section. This is largely due to the greater proportionate stretch as the iron approaches breaking; and the amount of the increase depends, as noted in (1) above, on the ability of the outside layer to stretch. The outside layer is seen to be very important in determining the behavior of a cast iron beam, and this is just the part that is most sensitive to small variations in the mold and to other conditions affecting cooling.‡

---

*That eminent authority, Mr. Thos. Turner, gives tables to show, however, that the *maximum* transverse strength and maximum tensile strength do not co-exist in the same iron. See "Metals," by A. K. Huntington and W. G. McMillan, Ed. 1897, p. 213.

†The ordinary formula for a beam supported at the ends and loaded at the middle is $W = \frac{2}{3} \frac{bd^2f}{l}$; where b = breadth, d = depth, l = length between supports, and f = tensile strength per square unit. Applied to the test bar, with iron of 20,000 lbs. per square inch tensile strength, which is fair: $W = \frac{2}{3} \cdot \frac{2 \times 1}{24} \cdot 20{,}000 = 1110$ lbs. The test bars stand about 2000. The formula is more nearly correct below breaking.

‡For discussion of the behavior of cast iron in transverse test, see article by Prof. J. B. Johnson, Trans. Am. Soc. C. E., Vol. 22, 1890, pp.

These facts probably account for the erratic behavior* of test bars, and argue for great care in methods of making bars. The strength of pipes also must be affected by conditions of the mold or other circumstances affecting the cooling of the iron. Pipes turned out while still red, or pipes overheated in coating, may be injured. The planed bars of Foundry Y (see Table I, lines 16-19 and 44-49) were designed to avoid the imperfections of the outer skin. The iron in them was very noticeably coarser than that in the smaller 2 x 1-inch test bars cast from the same iron; and probably the iron in the planed bars was considerably lower in both tensile and compressive strength; but the planed bars stood, on the average, a little more load than the unplaned, and always deflected very much more. The larger transverse strength of the weaker iron was apparently due to the greater stretch of the outside layer, which allowed the inner iron to be brought into play to a greater extent.

Evidently the transverse test is a complex subject; but the pipes also have an outside skin and are much more often broken with the iron in transverse stress (by shock) than otherwise; hence it seems that the transverse test is a logical one, though perhaps impact tests would be more logical than are quiescent tests.

For pipes about ½ to 1 inch in thickness, then, the transverse tests of 2 x 1 x 24-inch bars probably furnish us with at least a quasi-direct indication of the tensile as well as the transverse strength of the iron; and the conclusion might be drawn that it would be safe† and wise to choose for these pipes iron giving the highest strength (coupled with high deflection) consistent with capability of being cut and drilled.

Pipes less than about ½ inch in thickness are probably of closer texture than the corresponding 2 x 1-inch bars. Hence the maximum strength of pipe would correspond to a test bar of a somewhat weaker and more open texture, and the maximum strength of bar might correspond to pipes of white brittle iron, especially with very thin pipes. Irons differ greatly, however, in the effect of size and casting on their texture.

Pipes more than about 1 inch in thickness are of a more open texture than the corresponding 2 x 1-inch bars. The writer has seen some pipes 1.4 inch in thickness that were of very much coarser texture than the corresponding bars; and, again, some that were only slightly more open; but never any that were closer than

---

98-109. "Applied Mechanics," Prof. G. Lanza, Ed. 1897, pp. 381-390. Article by Prof. J. Sondericker in *Technology Quarterly*, October, 1888.

*See conclusion 7, p. 241.

†See, however, p. 237 *et seq.*

corresponding 2 x 1-inch bars. Iron in these pipes is probably weaker than iron in bars, except when the texture of the bar is closer than that corresponding to maximum strength for the particular iron,—*i.e.*, except when the bar is well toward white,* or chills at the corners.

Such is the theory that the writer came to accept as applicable to ordinary foundry irons. Subsequently the tables summarized in Tables I and II were compiled, in the hope, among others, of testing the theory.

About 0.7 per cent.† of the larger pipes and 6.3 per cent. of the smaller pipes shipped were found to have been split from the time of casting to that of laying. The results of bars cast on the days‡ with these split pipes were separated§ and studied individually and by average. Bars cast on days having burst pipes were studied similarly. Except in one case, the averages of these bars were not very different from the general averages of Table II, and the low individual results were no more common. In one case the bars cast with burst and split pipes were decidedly low;|| and the result, taken alone, looks significant.

Hence we may regard the averages of columns 2 and 3 in Table II as representing the quality of iron in split and burst pipes about as well as it does that in the other pipes, except in the case of Y_2. There is nothing in the precentage of burst and split of "large pipes" which would indicate any marked superiority of pipes cast with stronger bars over pipes cast with weaker bars; or *vice versa*. The percentages of split pipes are small and differences can be properly attributed to accident, though foundry Z pipes not only show superiority in the table, but also are considered best by M. W. W. pipe yard men.

In "smaller pipes" Y_2 has only a few split and burst, and the corresponding bars were of low strength. The other foundries, however, though giving stronger test bars, have large numbers of pipes split in transit. The discrepancy is so large that one cannot help wondering if it is all accident; and it throws a slight, but unpleasant, uncertainty over our theorizing; for these smaller pipes

*Some of the strongest bars the writer ever tested (about 2800 lbs. and 0.40 inch deflection) were of mottled iron. A heavy cylinder (5 inches thick) of this metal was satisfactory, but a small flange pipe was considered too hard.

†In all 288 out of 11,450 shipped, or 2.5 per cent.

‡The bar, if any, cast with a particular pipe is rarely known. See pp. 229-30, infra.

§See Table I, lines 11, 12, 23, 24, 25, 29, 30, 34, 35, 38, 41, 52, 53.

||See Table I, line 24.

are of just about that thickness which the writer had selected as being best indicated by the test bars. The results may be explained by one or more of several hypotheses:

1. The most obvious hypothesis is that the number of split pipes is so largely a matter of chance roughness in handling that the results do not truly indicate the relative strength of the pipes. The only reason that can be urged for giving any weight to the number of split pipes, as an indication of the strength of the pipes, is the assumption that, with so large a number of pipes, the differences in handling would average up in the long run and the stronger pipes would come out ahead.* Moreover, one of the Met. W. W. pipe yard sub-foremen, who received most of the smaller pipes included in Table II, and assisted in cutting off the split portions of these pipes, states that "there was something wrong with the iron" of those broken pipes; that they were brittle and tended to crack off unevenly in cutting. The foundry Y pipes, on the other hand, were found of softer iron and cut smoothly.† These facts indicate that the high percentage of split pipes was really due to brittle iron, though the test bars were strong.

2. Our test of bars is by slowly-applied load; whereas, in practice, pipes are broken by sudden shock. Perhaps iron may be strong and elastic under slowly-applied load and still weak under shocks. If load only were observed, and not deflection, this hypothesis would not lack supporting evidence; but it does not seem probable that iron, having both load and deflection high, can be brittle even under shock. The enduring of stress is, however, connected with intermolecular movements about which we cannot reason confidently.

3. It may be that the test bar is not so good an index of iron in the corresponding castings as we would fain believe, even when its texture appears to be nearly like that of the casting. All who have studied the behavior of iron in transverse test, particularly, agree that it is complex. Moreover, differences, too small to be noticed by the eye, may be important in their bearing upon the internal condition of the iron.

---

*And the difference in strength of foundry Z and foundry Y pipes is seemingly not slight. If the quiescent load and deflection of the bars were an index of the ability of the pipes to bear shock, then the pipes would be able to absorb work proportionally to the products of the test bar loads and deflections: Z pipes : Y_2 pipes : : 2310 x .420 : 2030 x .352 : : 1.36 : 1 : that is, Z pipes would be about 1-3 stronger.

†The same foreman asserts, and from much experience, that among the larger pipes foundry Z pipes are clearly the toughest and most convenient for cutting, while foundry Q pipes are very hard to cut smoothly, as they tend to crack.

4. The most plausible hypothesis, however, seems to be that removing the pipes red hot from the molds renders them brittle. We have seen how important is the outer skin in determining the behavior of iron under stress. Columns 17 and 18 of Table II show the facts in regard to turning out the pipes. Unless a determined effort is made by consumers, pipes will continue to be turned out red hot, as the delay of allowing pipes to stay in until cool inconveniences the founder and diminishes his output. It may be that a more open grade of iron, of low strength in test bars, stands being turned out hot better than closer, stronger iron; but as the lower strength is liable to be due to other causes than openness, it would be futile to specify low strength.*

At the outset the writer thought that the transverse tests of a single size of specimen bar would be most safely treated as wholly indirect† tests, from which point of view one would not necessarily be surprised even if weaker bars (in quiescent test) accompanied stronger pipes in some cases. The contradictory nature of the results, however, and the evidence that irons of different natures could have the same test bar strength and deflection, enjoined the application of the theory.

The matter of chemical durability of pipes seems to be more amenable to reason and deserves our attention.

CONCLUSIONS ON TESTING.

1. Owing to differences in conditions of cooling, no test bar can be a true sample of the iron in its corresponding casting. The differences are further complicated by more or less marked variations in texture from center to surface in both test bar and casting.

2. Judging by the appearance of iron in corresponding pipes and test bars, the 2 x 1-inch bar gives a fairly good sample of iron in pipes of about ½ to 1 inch in thickness. Iron in thinner pipes will be closer and usually stronger‡ (in gradually applied stress, at least) than iron in corresponding bars; and iron in thicker pipes will be more open and usually weaker‡ than iron in corresponding pipes.

3. The transverse test shows neither the tensile nor the compressive strength of the iron in a bar, but involves a complication

---

*See footnote, p. 234.

†See pp. 227-8.

‡Lines 9 and 10, 21 and 22, 32 and 33, of Table I, give comparisons between pieces, with *planed surfaces*, cut from pipes and bars with the *skin* on. The comparison still shows greater strength of test bars, but is not a fair comparison, as will be evident from p. 236.

of conditions that defy accurate determination. The following statements, however, appear to be true:

(a) Transverse strength usually increases with tensile strength of iron, and with stretch of the outside skin of iron.

(b) Deflection increases with the stretch of the outside skin of iron.

The nature of the outside skin* is seen to be a very important factor in the behavior of iron under transverse stress, as it is also in tensile stress.

4. Notwithstanding the complexity of the transverse test, it seems to be the best single test for general use, because deflection, as well as strength, can be readily measured. Moreover, it is particularly appropriate in pipe irons, because pipes usually break with the iron in transverse stress. However, as this stress is generally caused by shock, perhaps a good impact test would be more logical.

5. The writer accepts it as probable that the strength of pipes that have not been turned out of the molds red hot is measured in a rough comparative way by the strength and deflection of the 2 x 1-inch test bars. It is sure that exceptions to the rule will be found, as, for example, in the case of thin pipes (say $\frac{3}{8}$ inch and less) cast with some irons.†

These conclusions rest upon the general impressions of the writer gained from examining fractured sections of pipes and bars, the impressions of men who cut and handle the pipes and the general plausibility of the idea, in spite of recognized complexities. That iron of, say, 2300 pounds—0.40 inch test bar strength makes stronger pipes than iron of 2000—0.35 cannot apparently be proved with certainty, however, by use of the pipes. A large factor of safety against water pressure, and chance in the matter of breakage by handling, cover up the differences.

6. The large percentage of split pipes of the smaller diameters, from foundries having the stronger test bars, and the opinion of pipe yard men, gained from cutting off broken spigot ends, that these pipes were brittle, seem most reasonably explained by the fact of the pipes being turned out while still red hot.‡ Unless

*It would seem that making bars in a baked mold, as the pipes are made, would minimize the differences between bars and pipes due to difference in character of skin.

†See p. 236. According to the writer's observations, ordinary grades of iron become too hard for convenient cutting and drilling before they attain their maximum strength. Hence, with good inspection, there would be little danger of getting iron weak on account of being cast in too thin pipe.

‡See Table II.

these results can be attributed to this cause, or to chance, the fifth conclusion is untenable.

7. The precision of a single transverse test of 2 x 1 x 24-inch bar is very low. Flawless bars, cast from the same bath at the same time, under conditions as nearly similar as possible, varied on the average about 100 pounds in corrected load and 0.03 inch in corrected deflection. Moreover, much larger variations were common, the maximum variation in load being 440 pounds, and the maximum variation in deflection being 0.088 inch, and there were seven differences exceeding 200 pounds.* These erratic variations are as great as those between irons of widely different natures. It is pertinent to ask whether the pipes vary as much in strength as do the bars.

8. Notwithstanding the complexity of the transverse test and the low precision of results, the regular testing of 2 x 1-inch bars for transverse load and deflection enables the observer to detect the larger variations in charging the cupola during a heat and from day to day, as the writer can testify from experience. The careful examination of the texture of the fractured sections of the test bars aids greatly in judging the iron. Appearance usually corroborates results of tests.

9. The test bar does not in any degree supersede the function of the experienced inspector, though it should aid him in judging the iron. Not only is the inspector indispensable in discovering imperfections in castings, but his opinion of the iron, obtained from observation of its behavior under the hammer and from seeing rejected castings broken up, serves as a valuable check on tests which have not our perfect confidence. Moreover, the inspector must say whether the iron is suitable for cutting and drilling.

10. The following methods of making and testing bars are believed to be preferable:

(a) Use dry sand molds in iron flasks. A core spindle 4 to 6 inches in diameter will serve well.

(b) Use an iron pattern and pull it lengthwise, so as to have no seams or fins on the bars.

---

*These results obtained from eighty-five pairs of bars, forty-three pairs being green sand cast in separate flasks; and forty-two pairs being dry sand, the two bars of a pair being gated together and poured as one casting. A set of bars, cast to see whether green sand or dry sand bars are stronger, resulted as follows: Green sand bars exceeded in ten pairs by 155 pounds in load and 0.049 inch in deflection, on the average; dry sand bars exceeded in seven pairs by 111 pounds and 0.024 inch on the average.

(c) Dip the iron for the bars from the large ladle just previous to pouring the pipes or other castings.*

(d) Allow the bars to remain in the flask until cool.

(e) In testing, maintain a stated speed. Many of the Metropolitan Water Works' tests have been made at the rate of about 0.4 inch deflection in 2 minutes. If mechanical power were available, it would insure greater uniformity.

(f) If green sand bars are used, apply the load so that the "cope" side of the bar, which is almost invariably somewhat imperfect, shall be in compression.

(g) The writer would have at least two bars cast with every test ladleful of iron, in order that the degree of precision of the tests may be constantly known. And this, even though only two bars were allowed for the heat. In the latter case the inspector could guard against fixing one part of the heat by changing at will the time of pouring bars.

11. Planed bars are so entirely different from unplaned bars that no true comparison of irons can be had by comparing results of planed bars from one iron with those of unplaned bars from another iron. Bars cast $2\frac{1}{2}$ inches x $1\frac{1}{2}$ inches, and planed on four sides to 2 inches x 1 inch, deflect about 50 per cent. more than unplaned 2-inch x 1-inch bars of the same iron.

12. Rumbling bars for about thirty minutes increased the strength from 8 to 12 per cent., and the deflection about 15 per cent. Hence, in judging iron, rumbled bars are not to be compared with bars not rumbled.

13. Bars containing considerable flaws, especially in the tension side, are of no use as tests of the strength of an iron, though they may show that flaws are due to the iron and would be liable to occur in the pipes.

14. Some of the uncertainty in the use of test bars would be eliminated by a practical application of Captain Henry James's idea of having bars of the same thickness as the castings (see p. 226). It would be well to modify the idea, and have bars of a thickness *equivalent in cooling* to that of the castings.

The following is a suggestion for such a method for pipe iron:

(a) For pipes 0.4 to 0.5 inch thick, use bars 2 x 0.6 inch.
(b) " " 0.5 " 0.9 " " " " 2 x 1 "
(c) " " 0.9 " 1.4 " " " " 3 x 1.5 "

---

*It may be well to state that a mischievous foreman could often increase the strength of his test bars by stirring a few steel borings or turnings into the iron in the hand ladle.

All bars to be cast in dry sand, as are the pipes.

The reason for the excess of thickness of the bars is that iron in bars cools more rapidly than iron in pipes of the same thickness, for obvious reasons. The relative thickness of pipes and bars here given was based on impressions of appearance of fractured sections of pipes and bars, and a few careful comparisons. No study was made, however, with this particular purpose in view.

The proposed system is still palpably defective in that the test bar has four cooling surfaces, hence four planes of intersection of crystalline structure, four sides having the closer skin of iron, and four corners, which cool rapidly and chill when the iron has a tendency to chill. In a few instances the tension corners apparently (judging by snapping noises) break before the rest of the bar. In the other cases they must determine the deflection at which the bars break, thus limiting the results. A section of a pipe, on the other hand, has only two cooling surfaces. The difficulty might be avoided by planing, from each of the two sides of the bar, a layer equal in thickness to about half the thickness of the bar; the bars could be made wide enough to plane to 2 x 1 inches. A few bars of this kind, which would of course cost considerable machine work, would show more, in the writer's opinion, than many unplaned bars.

15. Finally, it should be remembered that the matter of chemical durability has been neglected in our tests, though it would probably be wise to pay attention to this side of the question of suitable iron.

(c) Chemical Analysis.

This also is an indirect test of the physical properties of iron, depending for its utility on the data that have been collected in regard to the physical behavior of irons of certain compositions. The chemical composition of a given iron is probably an exact characterization of that iron in so far as the composition can be accurately determined. There is no doubt that iron in a new casting is like that in an old casting, provided the chemical composition of the two irons is identical.* Hence chemical analysis bids fair to furnish a scientific method of duplicating satisfactory irons, thus making the results of experience available for present use. Of course the application of the chemical method is not nearly perfected, but it has been carried far beyond the published facts by a few of the larger works that have employed chemical and physical test for years. It would be possible, even with the present

*Contrast statements in regard to physical test on p. 228.

knowledge available on the subject, to specify certain compositions of iron that would give very satisfactory castings, and in time chemical specifications will probably be commonly made. At present, however, it would be expensive (in first cost at least) to carry out such specifications.

Chemical analysis might be used, under the present system, in cases of doubt to aid the engineer in deciding as to the suitability of certain castings.

Coatings for Cast Iron Water Pipes.

It is probable that nearly every engineer who has had a large number of pipes to lay has resolved that he will do something to dispel the mist that hangs about the subject of preservative coatings. Very many seem to have made concoctions of coal tar, asphalt, linseed oil and other things, in the endeavor to strike the fortuitous combination of cheap products which would adequately protect the metal. If all these experiments could be published the engineering world might finally arrive at a choice by rejection. As it is, the same ground is covered several times over with the same disappointing results. The question of preservative coatings belongs properly to the skilled chemist, but it has been attacked with some assurance by persons (including the writer) who are not chemists. The results of the writer's observation, study and experiment, made in connection with the Metropolitan Water Works, will be given.

COAL TAR COATING.

The details of the application of this coating have already been described.* Coal tar is a very complex mixture; indeed, the fact is so well known that people are not seldom heard calling a doubtful drug "one of those coal tar products." Moreover, coal tar varies very widely according to the coal used and the temperature maintained in the manufacture of the gas. Furthermore, crude tar varies at different heights in the tank in which it is collected at the gas works. But no tests are made to obtain any particular kind of tar for coatings. The unrefined overflow from the hydraulic main of the gas plants is purchased where it can be obtained easiest and cheapest. Specifications often call for deodorized tar, but the most noticeable thing about coating tar is its dense and pungent fumes when heated.

The degree of fluidity of the tar varies with the composition and with the temperature. In summer tar is usually more fluid than molasses; in winter it has often to be melted out of the barrels.

---

*See p. 222.

This crude tar cannot be used as a paint for cold surfaces, because it will not harden. And tar from the coating vat, though always somewhat refined by the continued heating, does not harden sufficiently when applied to cold surfaces. This suggests the philosophy of the whole tar process of coating. By the heat of the pipes the tar is distilled down to a compound which is solid at atmospheric temperatures. A very favorable condition for this volatilization of the liquefying constituents (which are also the most volatile constituents) evidently exists when the tar is exposed to the air, spread, as it is then, in a thin film over the hot pipes; and that rapid volatilization takes place at this time is indicated by the dense fumes given off.

As a corollary to the foregoing it follows that the temperature of the pipe, as it *emerges* from the tar bath, is one vital factor in the character of the coating. If the pipe is too hot, the coating is over-distilled and becomes too brittle, or may even be reduced to earthy, carbonaceous residuum. If the pipe is too cool, a thicker coating is formed, which will not harden sufficiently, will come off on the skids and will run in warm weather. Thin pipes must be heated hotter than thick pipes, because the thin metal does not hold the heat so long, and hence the distillation must be more rapid at first. The writer made an attempt to measure the temperature of some pipes just before they were dipped. An ordinary thermometer was of course of no use, nor could an electrical device be found which experts would recommend to record such low temperatures. Hence the writer procured several chemicals which are said to pass through noticeable changes at certain fixed temperatures: red iodide of mercury, which is said to change to the yellow at about 300 degrees F.; yellow stick sulphur, which fuses at about 235 degrees F., and silver nitrate, which fuses at 424 degrees F. Every pipe which was tried turned the red mercuric iodide to the yellow form, but no pipe, apparently, fused the silver nitrate. The effect on the latter and on the sulphur was hard to observe on account of the heat and smoke; hence the only conclusion that could safely be drawn was that pipes, just before coating, are usually considerably over 300 degrees F. With tar and thickness of pipe so variable, the proper temperature must be a matter of judgment on the part of dipman. A reliable and handy pyrometer would help, however, as it would enable the dipman to use the experience gained on one pipe in judging of the next one.

There is no question about the importance of having ovens properly arranged to heat the pipes uniformly. The brick fire arch, having bricks left out at intervals all along the position of the

pipe, is rather satisfactory. The single opening at one end of the pipe is decidedly unsatisfactory. The soot that is deposited on the pipes may do some harm. More elaborate and more nearly perfect schemes for heating pipes will quickly suggest themselves, but it seems probable that a careful application of the present methods will give results as satisfactory as a crude tar coating warrants. Careless application will vitiate any method. Thus, at one foundry the pipes are often wittingly under-heated on days when strong northerly winds prevail, because the wind makes it difficult to heat the ovens, and the day's work must be done just the same. Again, the pipes which stay in the oven during the dinner half-hour are liable to go into the tank too hot, because they are left in the oven too long and are not allowed to cool down. In general, the men fall into a certain routine of work,—so many pipes to brush out, so many to mop out, so many to roll into the oven, etc., between dippings,—and this routine fixes the time of heating. A good dipman will not allow very noticeable errors in temperature to pass, but he will not delay the routine for minor errors. In other words, the application of the method is inferior to the best judgment of the dipman.

The character of the tar in the bath is another important variable. New tar gives softer coatings, other things equal, because it contains more of the lighter constituents. Thick tar gives thicker coatings than thin tar. The temperature of the pipe should be varied to meet variations in the coating compound. Fresh tar requires a hotter pipe than does old tar. Regularity in adding new tar would give greater uniformity in coatings, but tar is often not in stock when it is needed, and the dipman does not care much, so long as the coating passes—and the inspectors do not usually pretend to know much about coatings or to judge them very harshly.

The temperature of the tar itself does not count for much when the pipes are heated before being dipped, as is universal now. In the old method of heating the pipes by allowing them to remain in the dip half an hour or so, the temperature of the dip was very important, though less so than it would have been with crude tar. The temperature of the tar in the present method is usually about 220 degrees to 230 degrees F. Observations of men at the foundry on temperature of the dip, and the writer's observations on small quantities of tar, indicate that new tar, on account of the lighter constituents,* does not at first rise above 220 degrees F.

*The law of fractional distillation is that a mixture, when distilled, remains at the boiling temperature of that constituent which boils at the

Later it rises to 350 degrees F., if heated sufficiently. It is evident that the old method of allowing the pipes to come to their proper temperature in the dip would lead into difficulty if the crude tar was fresh in the tank, as it would be difficult or impossible to raise the pipes to the required 300 or more degrees.

Small pipes are, as a rule, carelessly heated, and the writer has often seen very hot pipes lowered into the tank, where they caused a violent boiling and much yellow smoke (yellow smoke is the founder's sign of an excessively hot pipe). An inspector said that at one foundry pipes hot enough to set fire to the tar are so common that lids are rigged so that they can be rapidly unhooked and allowed to fall over the tank and smother the flames.

DEAD OIL.

Specifications often call for the use of dead oil of coal tar in the dip. Dead oil is defined as that part of coal tar which is obtained, in fractional distillation of coal tar, between the temperatures of 410 degrees and 750 degrees F. approximately. It contains both the creosote and the anthracene oils. Whether the commercial article agrees with this definition is unknown to the writer.

Some commercial dead oil that the writer tried evaporated about one-seventh as rapidly as water, both being exposed to the air. A brown cake was left in the bottom of the vessel. The misconception is probably often entertained that dead oil bears to tar coating a relation similar to that of linseed oil to paint. A better comparison would be that between dead oil in coal tar and turpentine in paint. Dead oil is of use principally to thin back the tar when it becomes thicker than the dipman likes it. Ordinarily the necessary adding of fresh tar is sufficient to keep the tar thin. At one foundry no dead oil would ever be used if the engineer did not occasionally require it. At another foundry it is the regular practice to use one barrel of dead oil to about seven of coal tar. A change was made at one foundry from no dead oil to about the above proportions, but it had no visible effect on the character of the coating. The effect on the composition of the tar dip was to increase the proportion of the heavy oils in the tar from about 25 to about 35 per cent., and perhaps the change really did improve the coating.

TAR AND LINSEED OIL.

The use of linseed oil in tar coatings dates back to the first

---

lowest temperature until that constituent is gone; then rises to the next lowest boiling point and remains there, and so on.

tar coating of Dr. Robert Angus Smith, a patent for which was taken out in Great Britain in 1848. The patent states that pipes were first to be cleaned and then preferably coated with linseed oil. Pipes might be heated before dipping or allowed to come to a heat in the mixture. The tar was distilled to "a thick, pitch-like mass," and kept at a temperature of about 300 degrees F. Pipes were left in the dip about thirty minutes. Dr. Smith found it "desirable to pour a quantity of linseed oil on the coated surfaces," which process had "the effect of removing any excess of tar, and the oil running into the tar kept it fluid and prevented its becoming unsuitable for further use." Such was the first coating of Dr. Smith. The writer found several different coatings described as Dr. Smith's, and it is probable that the doctor improved on his original one. The foundrymen to-day often call the crude tar coating in present use "the ordinary Angus Smith coating." In "Water Supply of Cities and Towns," by William Humber (published 1876) two methods used by Dr. Smith are given. In both, the dip contained gas tar, Burgundy pitch, oil and resin, the percentage of linseed oil in the second method being five or six. In the first of these methods the pipes were heated to from 400 degrees to 500 degrees F., and the dip was also kept hot. In the second, the dip only was heated, and the pipes were allowed to take the temperature (300 degrees F.) of the dip. It was supposed that the pores of the iron opened to receive the tar.

The questions that concern us now are whether linseed oil improves the quality of tar coating, and, if so, what method can be adopted for its use. On the first question we seem, as usual, to have no direct evidence. Old foundrymen will say that the present coating is not so good as the former coating was, but there are no comparative records available, so far as the writer knows. The writer has been unable to find out from records, or by questioning foundrymen, how much and in what ways linseed oil was used in the past, and when it ceased to be used. One very intelligent employe, who had been in the foundry business for about twenty years, thought there had been no linseed oil used at the foundries around Philadelphia since about 1872. Specifications throw little light on the subject, as they often contain directions that are not followed. It seems probable that the practice of using linseed was gradually dropped, perhaps on account of a change in the character of the tar obtained from the gas works, perhaps for other reasons of convenience; perhaps with the knowledge and consent of engineers, and perhaps without their knowledge. At any rate, the comfortable feeling of a question pretty well solved has con-

tinued; though perhaps, if the truth were known, the modern crude tar coating would be found to be living on the hard-earned reputation of the linseed oil coating. If records of the composition and behavior of coatings had been carefully kept and made available to students of the subject, many years of experience, now of little use, would have been saved to the world; and unless more care is taken, the next generation will make the same complaint.

In default of sufficient experience, we must resort to theory. The japan coating of Edward Smith & Co. is the result of careful theorization,* and the pamphlets issued by that firm, containing articles by Mr. A. H. Sabin, chemist for the firm, and by others give many facts in regard to preservative coatings. Mr. Sabin puts up a very strong plea for linseed oil, but he discards coal tar as a filler and accepts copals and also asphalt, which chemists usually consider as a more enduring compound than the complex and volatile coal tar. Mr. Sabin is also enabled to use a large percentage of linseed, and without any injurious dryer, because he bakes his coating. Now, whether or not the asphalt is better than tar, the arguments brought forth for the use of linseed seem pretty strong, and the writer would make use of them to give some evidence that linseed oil would improve coal tar coating.

Assuming, at any rate, that linseed oil would improve tar coating, the writer attempted to find out how it could be successfully applied to the present practice. At the McNeal Foundry an experiment had just been tried with an imported English tar and raw linseed, the fact that crude American tar could not be used with linseed having been proved at this foundry in previous years. The English tar was said to be somewhat refined, but appeared about the same as the American crude tar. The tar pit was cleaned out and English tar and raw linseed, in the proportions of ten tar to one linseed, were put in. The mixture became thick and lumpy, and all efforts to make a passably smooth coating failed. Even a temperature of 350† degrees F. failed to improve matters and pipes had to be recoated. No more linseed was added to the dip, but fresh tar and dead oil were added as needed, so that the proportions of linseed steadily grew less. Finally the tank was cleaned out and the use of crude American tar resumed.

The following is a description of some of the experiments tried by the writer with tar and linseed: The mixtures were made mostly in ten-quart porcelain-lined kettles. The specimens coated

---

*Also of much experience, though not with conditions such as exist in water pipes. †See note p. 250.

were fragments of pipes, the pieces being usually about 3 to 5 inches wide and 0.5 to 1.25 inches thick.

1. Twenty-eight parts of English tar and 1 part of raw linseed. The linseed, cold, was added to the tar at 240 degrees F. Violent frothing took place. The mixture soon doubled its volume and ran over. Coating out of the question for practical use on account of frothing and lumpiness.

2. Twenty-eight parts English tar plus 3 parts raw linseed that had been boiled for ten minutes. Ingredients mixed with tar cold and brought to liquid state at about 340* degrees F. Less frothing than before, but coating useless. Soft oil collected next the iron, and dull earthy tar outside. Dead oil helped matters somewhat, but coating remained useless.

3. Twenty-eight parts English tar plus 1 part commercial boiled linseed (guaranteed by an acquaintance as not having been boiled "through the bung-hole"). At 230 degrees F. violent frothing occurred; and, though a fairly good coating was obtained on a small scale, the method is out of the question for regular work. Dead oil did not help.

The foregoing experiments indicated that such crude tar could not be used.

4. In order to get tar at least somewhat refined, took 4 quarts of tar from the coating tank. Added $\frac{1}{4}$ quart of boiled linseed oil thereto. Frothing was too vigorous for any thought of practical application.

5. Boiled some crude tar for about $5\frac{1}{2}$ hours. At the start, the tar was a thin fluid at atmospheric temperature. After boiling, the tar was a soft solid at atmospheric temperature. During boiling, the temperature of the tar remained at about 220 degrees F. for about an hour, then rose to about 290 degrees and stayed there for a time, and finally became about 350 degrees.

To 16 parts of this boiled tar added 1 part of boiled linseed. No frothing occurred, even at 400 degrees F. The mixture was thick and did not harden sufficiently on fragments of $\frac{1}{2}$-inch pipes. Later it occurred to the writer to try thick pipes (an inch or more thick), and there was no difficulty in getting the coating even too hard. No frothing occurred when dead oil was added to thin the mixture.

The experiment showed that linseed oil could be used with partially refined tar, but it also indicated that the application of the method required more intelligent care than does the crude tar method.

---

*This temperature seems abnormally high in view of the other results.

Since making these experiments, the writer has found an old specification for tar coating, the method of which agrees so closely with the results of these experiments that the following quotation is made:* "The varnish, or pitch, is to be made from coal tar, distilled until all the naphtha is removed, the material deodorized and the pitch reduced to about the consistency of wax or very thick molasses. At least 8 per cent. of heavy linseed oil must be added." It is rather humiliating to come back to the results of thirty years ago. It would not be so if the old method had been deliberately abandoned for a better one; but, as already intimated, it is not apparent that such was the case.

Refined tar is now out of the market, though a tar residuum or pitch is used in roofing and for walks. As the above experiment indicates, it would be an easy matter to make some refined tar.

Procured some of the roofing pitch mentioned above. It is a solid, just viscous enough to slowly find its level in warm weather, but hard and brittle in cold weather.

6. Roofing pitch alone. Coating was thick and very glossy, but of course rather brittle. Such a coating might give excellent results if handled only in warm weather, but would probably fly off in cold. This coating has stood water tests for about a couple of years without losing its smoothness and lustre.

7. Nine parts roofing pitch and one of boiled linseed. A thick, glossy coating, not so brittle as pitch alone.

8. Nine parts pitch to 2 boiled linseed. Better than 7 as regards brittleness.

9. Nine parts pitch to 3 boiled linseed. Coating more bulky and less smooth than the others.

A greater proportion of the linseed would make the coating like paint, and drying would be too slow, unless baking were resorted to, as in the Sabin japan.

ASPHALT COATINGS.

It is truly charged against coal tar that it continues to decompose, so that finally nothing but a friable, earthy pitch is left. It is said to be characteristic of pyrogenic (fire-formed) compounds, to which class coal tar belongs, that they are unstable at ordinary temperatures. Asphalt also decomposes with exposure, as demonstrated at the natural asphalt lakes, but nevertheless is thought to be more durable than coal tar. The only direct long-time comparisons that occur to the writer are in the matter of walks and pavements, and here there is no doubt that the asphalt has demon-

*See Report of the Cochituate Water Board, 1867-68, p. 17.

strated its superior durability. However, the conditions in a water pipe are different from those of a street surface; moreover, a coating material might be very durable in *itself*, and yet not form an *impervious* coating, as is the case with pure linseed oil used alone. Asphalt has not the aggressive penetration of coal tar, nor does it stick to things and cover everything so persistently as tar. A little drop of tar will smirch skin, clothes, paper and everything that comes near it without apparent diminution in size, while asphalt can be handled with impunity.

The usefulness of asphalt as a pipe-coating compound for cast iron has never been demonstrated, though asphalt has been and is still used largely in coating steel pipes. Some information on its success for steel pipes should be available by this time, but little has been published.

The writer tried many experiments with Alcatraz, or California asphalt. Grades of several degrees of hardness are made, and by mixing grades it is comparatively easy to get a good consistency. A temperature of about 260 degrees F. was needed. The coating is not brittle, not very smooth, rather dull and not very tenacious. In fact, the impressions of the coating were rather of a negative nature. There were no glaring defects in the coating, neither was it very attractive.

Linseed mixes well with asphalt, but the coating does not harden unless a hard grade of asphalt is used.

P. & B. PIPE DIP.

This is a patent dip manufactured by the Standard Paint Company. Its principal ingredients probably are asphalt and candle tar pitch. The latter is a pitch obtained by distillation of animal fats. This coating has been used somewhat on steel pipes, but not long enough for a test of durability. As applied to cast iron it gives a coating very similar to asphalt coating,—*i.e.*, not hard, not brittle, not very glossy, not very tenacious.

MINERAL RUBBER DIP.

This is a dip manufactured by the Assyrian Asphalt Company. The process is not patented, but is secret. The appearance indicates that the compound is largely asphalt, and the coating is somewhat similar to asphalt coating, only duller in appearance. The dip requires a temperature of about 400 degrees F. This dip has recently become very popular for steel pipes.

VARNISHES.

There are many cheap varnishes made from tar, and there are also more expensive ones containing asphalt and other ingre-

dients. These varnishes consist of some solid dissolved in a volatile carrier, which quickly evaporates, leaving the solid on the coated body. The engineers of the Metropolitan Water Works have used a number of these varnishes in painting over the coal tar coating, with the idea of filling up the pores in the coating. The writer has experimented with some of these varnishes.

1. P. & B. Universal Paint, manufactured by the Standard Paint Co. This is to many a very familiar varnish, because it is not forgotten after having been once used. The solvent contains carbon disulphide, the odor of which is sickening to most persons. The coating seems fairly good after it is on, but the odor interferes with its use.

2. P. & B. Ruberine, also manufactured by the Standard Paint Co. This varnish consists of "ruberoid" dissolved in naphtha. Ruberoid consists of California asphalt and candle tar pitch digested and vulcanized with sulphur. Ruberine dries rapidly and is hard to spread smoothly. It gives, however, a substantial, rubbery coating.

3. Tar varnishes. Two of these were tried, one an American and the other a Dutch product, imported by Paul A. Davis, of Philadelphia, and said to be much used abroad. The varnishes were thin, had the coal tar penetration, and gave smooth, good-looking coatings.

It is evident that the use of varnishes would be very limited, unless it were found possible to use them as dips; their rapid evaporation seems to preclude their use in this way; but trial alone, and on a large scale, would settle this question.

TESTS OF COATINGS.

Of course the only satisfactory test of coatings is actual use under known conditions. Small-scale experiments are often misleading and always inconclusive. Moreover, all coatings are so durable that it takes a number of years to form an idea of their relative value, and by that time something new is often favored on theoretical evidence. However, the small specimens used in the experiments above described were subjected to several tests.

1. Test for brittleness. Most of the specimens were tested by hammering to see whether the coating was liable to fly off in handling of pipes. Allusion to brittleness has been made in describing the coatings.

2. Test of porosity. It is known that tubercles start at minute holes in coating. It was thought that if acid did not injure the coating material itself, it would give a test of the porosity of

coatings by attacking the metal through the pores. Specimens of coated iron were put in glass jars containing a mixture of one part muriatic acid and two parts water. At the same time samples of the coating materials alone were put into other glass jars with acid of the same strength. Great activity was immediately apparent in the case of the coated iron, and a disagreeable gas with a sweetish odor was evolved. The coating materials alone, on the other hand, were apparently not acted upon. Their appearance, and the appearance of the acid in which they were submerged, remained the same to the end of the test, which was almost as long as the test of the coated iron.

The coatings were all badly undermined, and all but a specimen of Sabin's japan peeled off in many places. The iron was dissolved to the depth of $\frac{1}{8}$ inch in places, especially at the corners. The following is the estimate that was placed upon the specimens, beginning with the least injured:

TABLE A.

	Coating.	Time Exposed.	Remarks.
1.	Sabin japan	55 days.	Specimen said to have been rusty before being coated.
2.	Crude tar	55 "	
3.	Tar and linseed	60 "	No distinction possible.
	Alcatraz asphalt, pitch and linseed	60 "	
	Mineral dip (Assyrian Asphalt Co.)	55 "	
	P. & B. dip (Standard Paint Co.)	55 "	
4.	Alcatraz asphalt	55 "	
5.	All the varnishes	55 "	Totally destroyed.

There was *only one* specimen of each coating.

3. Running water test. The following specimens have been kept in running Boston water. Many tubercles have already formed on corners and on the rough fractured edges, but only a few* on the smooth large faces that formed parts of the inside and outside, respectively, of the pipes from which the specimens of iron were broken. The writer's estimate of the coatings is as follows:

TABLE B.

	Coating.	Time Exposed.	Remarks.
1.	Tar and linseed	2 years.	The coating is smooth and in good condition, except for a group of five ¼-inch tubercles.
2.	Mineral dip	2 "	Few tubercles on large surfaces, but coatings rather earthy.
	P. & B. dip	2 "	
3.	Alcatraz asphalt	2 "	Badly tubercled and covered with crumbling blisters.

*This does not include the numerous tubercles, due perhaps to galvanic action, that were formed at many places along the copper wire wound around the specimens to suspend them by.

There was only one specimen of each coating.

The following samples have endured four months in running Delaware River water,—whereby they were scarcely tubercled at all, but received a heavy coat of mud,—washings to remove the mud, and finally seventeen months in running Boston water, where they still are. The specimens have only three to five incipient tubercles* and a few specks on the large surfaces, though there are a good many well-developed tubercles, as usual, on the rough edges of fracture and around the copper suspension wire. In general appearance the writer would rank them as follows:

TABLE C.

	Coating.	Remarks.
1.	Pitch,	Coating still glossy.
2.	Pitch and linseed,	Coating still glossy.
3.	Pitch and linseed, painted over with Dutch varnish.	
4.	Mineral dip, P. & B. dip,	Tubercles not more numerous than in the case of the foregoing specimens, but the surfaces rather earthy in appearance and not smooth.
5.	Dutch varnish.	Freer from tubercles than any of the other specimens, but the surface is earthy and friable, black powder being easily scraped off.

There was only one specimen of each coating.

The following specimens endured the same treatment in Delaware water and subsequent washing off of mud, and were finally placed in a tank of water that is not often changed, where they have been about fifteen months. The tank has been used for much of the time for cement briquettes, and the water is hence very alkaline:

TABLE D.

	Coating.	Remarks.
1.	Pitch,	In good condition; few tubercles.
2.	Tar covered with Dutch varnish,	" " " " "
3.	Tar and linseed,	" " " " "
4.	Alcatraz asphalt, pitch and linseed, Tar,	" " " " "
5.	Mineral dip,	In fair condition.
	Alcatraz asphalt and linseed (2 specimens),	" " "
	Alcatraz asphalt, pitch and linseed (another specimen),	" " "
	P. & B. paint (2 specimens),	Few tubercles, but coatings are rather earthy, and black will rub off.
	Dutch varnish.	
6.	Mineral dip (another specimen) P. & B. dip, Alcatraz (2 specimens),	In bad condition; many well-developed tubercles; also crumbling blisters.

*A piece of pottery coated with Dutch varnish was not tubercled at all. This corresponds with the generally accepted idea that iron is essential to the formation of tubercles.

There was only one specimen of each coating except in the cases specially noted above.

The following table gives a *very rough* idea of the relative cost of the various coating materials. The crude tar results are based on actual records and are believed to be reasonably close. The other results are mere estimates, based, in the case of the dips, on the results for tar; in the case of the varnishes on estimated covering capacity; and in the case of the Sabin japan on results for steel pipes.

TABLE E.

Coating.	Approximate Amount required to coat one 48-inch pipe.	Approximate price.	Cost of Material for one 48-inch pipe.
Crude tar	3¾ gallons.*	$3 per bbl. of 52 gallons	$0.22
Pitch	5 "	$5 per bbl. of 52 gallons	0.50
Pitch and linseed			0.70
P. & B. dip	20 pounds.	$45 per ton	0.45
Mineral dip	20 "	$75 " "	0.75
P. & B. Univers. Paint	1½ gallons.	$1.00 per gallon	1.50†
P. & B. Ruberine	1½ "	$1.00 " "	1.50†
Tar varnish	1½ "	$0.10 " "	0.15†
Dutch varnish	1½ "	$0.25 " "	0.40†
Sabin japan	1½ "	$1.75 " "	2.60‡

CONCLUSIONS.

Should the Sabin japan prove by use to be as good as it appears to be, engineers would have to decide whether it were economical to add from 5 to 10 per cent. to the cost of pipes in order to prevent in part a deterioration, in the carrying capacity, which has been found as large as 20 per cent. in 16 years in even large pipes.§ But the efficacy of the coating must be proved by several years of use.

As for the above tests, the tar compounds seem to have the best of them on the whole (barring the Sabin japan, which was tested only by acid), though the tests are *too few* and *too short* to serve as a basis for decided opinions. The writer would like to try roofing pitch on some pipes. He has considerable faith in the efficacy of thick, smooth coatings, such as it makes. The experiments show that only a thick coating will protect rough surfaces and corners. If the pitch proved too brittle to stand the handling

*About 30 per cent. of this lost by evaporation.

†Estimated cost of the coating applied as by a brush. Wastage might be excessive as dip, but the latter would be the only practical way for use on a large scale; hence the figures above are not strictly to the point.

‡This coating requires a comparatively expensive plant and considerable skilled labor, which would largely increase the total cost.

§See paper by Desmond FitzGerald, Mem. Am. Soc. C. E., Trans. of Am. Soc. C. E., Vol. XXXV, 1896, p. 241.

of shipping and carting, it would not be impossible to have a portable coating outfit. The writer would also like to see a refined tar and linseed oil coating tried on the commercial scale. He would suggest that it would not be a very expensive experiment for a large city to try the several coatings on some line of its pipes and thus determine in a rational way what coating was best for its water.

Rusty pipes will apparently not hold a coating. At one foundry were several 30-inch pipes having only little blotches of tar coating left on them. The writer was told that these pipes were coated only two years before, but were very rusty when coated.

The foundry scale* which forms the surface of castings will protect the castings from rust for some time. Even when a casting is allowed to stand in a shower or two, only streaks of rust on top are formed at first. All chipped surfaces, however, quickly rust, and it is noticeable that coating over chipped surfaces is often quickly destroyed. Whether this is due to the surface being rusty before coating, or to a poor adhesion of the coating to even clean chipped surfaces, is unknown to the writer.

The writer wishes to acknowledge his indebtedness to Mr. Dexter Brackett, M. Am. Soc. C. E., who suggested the paper and gave advice and friendly criticism; to Mr. C. L. Prince, superintendent of foundries of the Camden Iron Works, who kindly loaned lantern slides and negatives; and to friends in the employ of the Metropolitan Water Board for information and advice.

---

*Silicate of protoxide of iron. See "Metallic Structures: Corrosion and Fouling and their Prevention." John Newman, pp. 124, 125.

TABLE I. General Summary of Test Bar Tables with Data on Corresponding Pipes.—Sheet A.

Note: This table contains results of most of test bars and pipes cast for the M. W. W., at four large foundries, between April, 1896, and February, 1897. For condensed summary, see Table II.

[1]Corrected Breaking Loads and Deflections. Below are given Average Loads and Average Deflections, Maximum and Minimum Loads with their Corresponding Deflections and Maximum and Minimum Deflections with Corresponding Loads. (Columns 9–18.)

Data in Regard to Corresponding Pipes. (Columns 19–25.)

No. of Line.	Foundry.	Description of Bars, etc.	Reference to No of Table.	Time embraced by Table.	No. of Bars in Table.	Col. 6 expressed as % total Bars.	% Worthless Bars.	Aver. Load. lbs.	Aver. Defl. in.	Max. Load. lbs.	Cor. Defl. in.	Min. Load. lbs.	Cor. Defl. in.	Max. Defl. in	Cor. Load. lbs.	Min. Defl. in.	Cor. Load. lbs.	Size.	Thickness.	Numb'r Cast.	% [2]Rejected.	% Cut.	% [3]Split.	Numb'r [4]Burst.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	X B	[5]Dry sand—Two bars in one flask, Part 1[6]	9	52 days[9]	132	62	15	2146	.340	2775	.384	1810	.307	.406	2588	.273	1870	48" A	1.15	725	17	7	.8	1
2	"	" 2			48	23		2076	.322	2640	.412	1725	.322	.414	2130	.270	1870							
3	"	Dry sand—Two bars in one flask, " 1[6]	10	40 "	49	52	26	2080	.347	2580	.366	1790	.302	.448	2070	.289	1850	48" A	1.15	320	31	14	.9	0
4	"	" 2			21	22		1989	.325	2395	.340	1790	.294	.387	2065	.278	1860							
5	"	Dry sand—One bar in a flask, " 1[6]	11	55 "	121	58	12	2081	.339	2475	.380	1730	.279	.398	2100	.271	1790	48" A	1.15	275	17	4	0	1
6	"	" 2			62	30		2051	.336	2400	.372	1730	.300	.427	2165	.283	1950	48" C	1.40	435	7	2	.7	0
7	"	Green sand—One bar in a flask, " 1[6]	12	68 "	193	69	13	2254	.362	2685	.404	1785	.307	.462	2675	.284	2020	48" C	1.40	715	8	4	0	0
8	"	" 2			52	18		2231	.354	2655	.373	1880	.347	.405	2615	.297	1870	48" A B	1.15 1.25	290	4	4	.7	0
9	"	Bars cut from pipe		1 "	2	100	0	2055	.5±	2060	......	2050	......	......	......	......	......	......	......	......	......	......	......	......
10	"	Corresponding regular bars		1 "	12	86	14	2071	.327	2440	.343	1825	.288	.385	2170	.288	1825	......	......	......	......	......	......	......
11	"	Cast with ladings containing	27	2 "	12	67	33	2260	.337	2655	.406	2025	.329	.406	2655	.309	2205	48" A	......	1 burst in each of the 2 ladings.				
12	"	burst and split pipes[8]	27	14 "	53	78	22	2094	.338	2655	.369	1400+	.17	.410	2055	.17	1400+	48" A B C	......	15 split in the 14 ladings.				
13	Y 2	[5]Rough green sand—tested drag up	22	54 "	83	53	47	1957	.314	2770	.278	1760	.296	.370	1935	.276 .278	1830 1970 2770	20" C 20" D	.79 .85	80 60	4 0	15 7	1 2	0 0
14	Y 1&2	Rough green sand (Rumbled[7]) tested cope up...	5	60 "	121	100	0	2225	.424	2460	.442	1930	.351	.479	2350	.327	2035	24" C	.87	340	8	4	.3	1
15	"	(not ")			86	100	0	2065	.367	2295	.395	1720	.296	.490	2255	.296	1720	36" B	1.03	75	15	6	0	0
16	Y 2	Green sand Tested cope up......: Cast 2¼" x 1½" and planed to 2"x1"	25	4 "	43	100	0	2048	.509	2235	.540	1755	.490	.555	2070	.460	2000	36" C	1.13	90	20	4	0	0
17	"	Corresponding 2"x1" bars			154	......		2025	.345	2250	.348 .389	1800	.301 .307	.398	2160	.287	1845	48" B	1.25	90	4	.5	.5	0
18	"	Cast 2"x1½" and planed to 2"x1"	25	3 "	3	100	0	2048	.419	2135	.439	1895	.379	.440	2115	.379	1895	48" C	1.40	360	2	3	1	0
19	"	Corresponding 2"x1" bars			10	......		2064	.349	2170	.379	1870	.300	.395	2140	.300	1870	20" C	.79	50	0	18	4	0
20	"	Dry sand—iron flask	23	46 "	46	96	4	2069	.376	2330	.404	1770	.291	.450	2080	.291	1770	24" C	.87	40	3	5	0	1
21	"	Bars cut from pipe		1 "	2	100	0	1900	.5±	1980	.6±	1820	.4±	......	......	......	......	36" C	1.13	85	19	12	3	2
22	"	Corresponding regular bars		1 "	1	100	0	2069	.343	......	......	Only	one	bar	......	......	......	48" B 48" C	1.25 1.40	105 970	2 1	3 7	0 .3	0 0
23	"	Ordinary rough green sand cast with ladings containing burst and split pipes[8]	29	10 "	22	71	29	1950	.332	2155	.401	1700+	.284 .322	.401	2155	.276	1970	48" B&C 36" C	....	9 split. 2 "				
24	"		29	2 "	10	100	0	1857	.310	2010	.315	1700+	.284 .322	.327	1835	.284	1700+	36" C	......	2 burst and 2 split.				
25	"		29	5 "	11	61	39	1972	.328	2120	.371	1835	.283	.394	2100	.283	1835	24" C 20" C&D	....	2 burst and 1 split. 3 split.				

[1]Bars are 24" span; and approx. 2" wide × 1" deep—Results corrected for variations from 2" × 1", as follows—Cor. Load = $\frac{\text{Observed Load.}}{\frac{1}{2}\text{ measured width} \times (\text{meas. thickness})^2}$. Corrected Deflection = Observed Deflection × measured thickness. [2]Rejected for all causes but test bars. [3]Split = split in handling or in transit from time of casting until laid, at some time usually unknown. (See foot note 3, table II.) % split is computed on number shipped, not on number cast. [4]Burst = burst in proving press. [5]Cast before test bars were made a cause for rejecting pipes. [6]Parts 1 include bars that showed practically flawless fracture; Parts 2 include bars showing some small flaws in fracture. [7]Rumbled for about 30 minutes in a cinder mill. [8]Bars with split pipes are of course included in the general averages. [9]Working days.

TABLE I.—SHEET B.

No of Line.	Foundry.	Description of Bars, etc.	Reference to No. of Table.	Time embraced by Table.	No. of Bars in Table.	Col. 6 expressed as % total Bars.	% Worthless Bars.	Corrected Breaking Loads and Deflections. Below are given Average Loads and Average Deflections, Maximum and Minimum Loads with their Corresponding Deflections and Maximum and Minimum Deflections with Corresponding Loads. Aver. Load. lbs.	Aver. Defl. in.	Max. Load. lbs	Cor. Defl. in.	Min. Load. lbs.	Cor. Defl. in.	Max. Defl. in.	Cor. Load. lbs.	Min. Defl. in.	Cor. Load. lbs	Data in Regard to Corresponding Pipes. Size.	Thickness.	Numb'r Cast.	%[2]Rejected.	% Cut.	%[3]Split.	Numb'r [4]Burst.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	Z A	Green sand...............................		148 d'ys[9]	563	95	5	2318	.422	2836	.465	1715	.313	.495	2420	.313	1715	36" D	1.25	205	8	4	.5	0
27	Z { A	" " { Rumbled[7]...............	6	17 "	34	100	0	2567	.470	2755	.505	2110	.345	.535	2600	.345	2110	48" B	1.25	615	2	2	0	1
28	{ F E	" " { not Rumbled.........	6		30	88	12	2284	.406	2605	.468	1935	.350	.470	2540	.350	1935	48" C	1.40	720	2	3	.1	1
29	Z A	Cast with ladings containing	30	3 "	10	83	17	2452	.423	2605	.421	2270	.428	.460	2485	.383	2560	48" B 48" C	1.25 1.40	1 split. 1 burst & 1 split.				
30	Z { A F	burst and split pipes[8]..........	30	8 "	31	97	3	2270	.424	2420	.465 .470	2080	.356	.480	2410	.356	2080	36" D 30" D&E	1.25 1.15			1 split. 8 split.		
31	Q	Dry sand................................		203 "	665	82	18	2063	.366	2550	.33	1803	.366	.465	2086	.270	2250	36" B	1.03	240	28	2	3	0
32	"	Bars cut from pipe........................		1 "	2	100	0	1996	.478	2015	.52	1975	.435	......	......	......	......	42" B 42" C	1.14 1.25	210 50	9 0	1 2	.5 .0	1 0
33	"	Corresponding cast bars...............		1 "	2	50	50	2120	.355	2140	.36	2100	.35	......	......	......	......	48" A 48" B	1.15 1.25	1035 305	28 8	4 5	1 .4	2 1
34	"	Cast with ladings containing	31	4 "	15	94	6	2060	.377	2130	.33	1970	.406	.436	2060	.31	2080	48" A 42" B	1.15 1.14	3 b'rst 1 "				
35	"	burst and split pipes[8]..........	31	16 "	53	83	17	2040	.365	2280	.34	1855	.33	.43	2020 2060	.30	2135	48" A & B 42" B & 36" B		........17 sp't				
		IRON FOR SMALLER PIPES.																						
36	X N	Green sand—One { Part 1[6].........	13	56 d'ys[9]	105	77	7	2103	.369	2515	.424	1780	.310	.540	2045	.285	1890	16" D	.75	845	[10]11	0	13	0
37	"	bar in a flask... { " 2			22	16		2011	.358	2585	.418	1765	.319	.472	2080	.284	1855	16" E	.81	430	19	0	4	0
38	"	C'st on d'ys hav'g no sp't pip's[11]	28	12 "	34	100	0	2120	.347	2445	.384	1780	.310	.419	2170	.285	1890							
39	X S	Green sand—One { Part 1[6].........	14	27 "	53	70	16	2276	.356	2745	.363	1710	.275	.420	2465	.275	1710	12" B	.57	150	38	0	2	2
40	"	bar in a flask.... { " 2			11	14		2290	.335	2605	.354	1795	.294	.367	2430	.294	1795	12" D	.65	155	16	0	.8	0
41	"	C'st on d'ys hav'g no sp't pip's[11]	28	5 "	15	83	17	2276	.355	2525	.337	1990	.312	.394	2235	.304	2115	16" B	.65	250	[12]33	0	17	0
42	Y 2	For bars corresponding to 20" and 24" pipes see Sheet A., lines 13 to 25.																						
43	Y 3	Green sand—one bar in a flask.	24	4 days	5	100	0	2111	.352	2270	.412	1935	.297	.412	2270	.297	1935	6" E	.50	97	0	1	0	0
44	"	" " { 2½" x 1½" planed to 2" x 1"	26	42 "	42	100	0	2000	.511	2230	.553	1840	.450	.580	2095	.450	2000	8" E	.55	68	1	7	0	0
45	"	{ 2" x 1½" planed to 2" x 1"		15 "	15	100	0	1921	.429	2130	.450	1730	.420	.490	2105	.350	1750	All from same cupola, which was used for small pipe work.						

Notes 1 to 9, see Sheet A. [10] 15% more rejected for deficient test bars. [12] 5% " " " " " ". [11] Days having *no* split pipes were the exception in these cases.

TABLE I.—Sheet C.

No. of Line.	Foundry.	Description of Bars, etc.	Reference to No. of Table.	Time embraced by Table.	No. of Bars in Table.	Col. 6 expressed as % total Bars.	% Worthless Bars.	Aver. Load. lbs.	Aver. Defl. in.	Max. Load. lbs.	Cor. Defl. in.	Min. Load. lbs.	Cor. Defl. in.	Max. Defl. in.	Cor. Load. lbs.	Min. Defl. in.	Cor. Load. lbs.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		¹Corrected Breaking Loads and Deflections. Below are given Average Loads and Average Deflections, Maximum and Minimum Loads with their Corresponding Deflections and Maximum and Minimum Deflections with Corresponding Loads.															
46	Y I	Green Sand { 2½" x 1½" planed to 2" x 1"	25	34 days[9]	34	100	0	2037	.495	2235	.510	1700	.480	.555	2140	.415	1820
47	"	Green Sand { Ordinary 2" x 1"	25	34 days[9]	66			2007	.335	2240	.345	1775	{ .295 .301	.410	2095	.290	1815
48	"	" " { 2" x 1½" planed to 2" x 1"	25	10 "	10	100	0	2057	.464	2250	.525	1880	.415	.525	2250	.405	2000
49	"	" " { Ordinary 2" x 1"	25	10 "	19			2006	.356	2165	.391	1870	.281	.414	2055	.285	1965
50	Z E	" "		48 "	175	96	4	2282	.417	2627	.510	1781	.422	.510	{ 2510 2627	.350	1960
51	Z F	" "		80 "	298	97	3	2287	.418	2587	.490	1685	.389	.485	2520	.330	1990
52	Z { E	Cast with ladings having split pipes	30	40 "	155	97	3	2310	.420	2585	.490	1975	.372	.490	2585	.351	2020
53	Z { F	"	30	15 "	58	97	3	2363	.429	2630	.510	1970	.333	.510	2630	.333	1970
		IRON FOR LARGE SPECIALS.															
54	X L	Dry sand—Two bars in a flask { Part 1[6]	15	26 "	37	67	11	1982	.337	2300	.388	1705	.293	.388	2300	.271	1755
55	"	" 2	15	26 "	12	22	11	1912	.328	2180	.381	1680	.271	.381	2180	.271	1680
56	"	Dry sand—Two bars gated together { " 1[6]	16	67 "	86	71	11	2025	.361	2390	.400	1650	.287	.449	1945	.272	1760
57	"	" 2	16	67 "	22	18	11	1940	.349	2445	.404	1635	.301	.407	1800	.301	1635
58	"	Dry sand—One bar in a flask { 1[6]	17	20 "	14	67	4	2362	.402	2835	.392	1860	.395	.460	2270	.350	1880
59	"	" 2	17	20 "	6	29	4	2268	.370	2650	.435	1955	.303	.435	2650	.303	1955
60	"	Green sand—One bar in a flask { " 1[6]	18	56 "	78	80	13	2343	.408	2665	.445	1925	.401	.530	2455	.346	2170
61	"	" 2	18	56 "	7	7	13	2321	.387	2805	.395	1815	.376	.445	2445	.337	2225
		IRON FOR SMALL SPECIALS.															
62	X J	Dry sand—Two bars in a flask { Part 1[6]	19	22 "	28	70	10	2126	.372	2525	.434	1800	.279	.442	2275	.279	1800
63	"	" 2	19	22 "	8	20	10	2069	.354	2275	.381	1750	.330	.403	2170	.330	1750
64	"	Dry sand—Two bars gated together { " 1[6]	20	50 "	60	62	19	2005	.377	2440	.405	1715	.377	.453	2335	.308	1915
65	"	" 2	20	50 "	18	19	19	1904	.359	2310	.420	1730	.357	.420	2310	.281	1855
66	"	Green sand—One bar in a flask { " 1[6]	21	62 "	94	82	6	2041	.396	2555	.454	1720	.340	.50	1960	.317	1920
67	"	" 2	21	62 "	14	12	6	1938	.382	2200	.384	1780	.340	.455	2170	.332	1845

Data in Regard to Corresponding Pipes.

Lines	Size.	Thickness.	Numb'r Cast.	% ²Rejected.	% Cut.	% ³Split.	Numb'r ⁴Burst.
	19	20	21	22	23	24	25
46–49	From iron used in small specials and pipes.						
50–51	16" D	.75	370	5	.5	11	0
	20" D	.85	490	8	.2	7	0
	20" E	.92	1035	4	.7	4	0
	30" D	1.10	230	10	2	3	0
	30" E	1.20	445	5	3	.5	0
52	20" { D	.85	28 sp't				
	20" { E	.92	31 "				
53	16" D	.75	33 "				
54–61	From iron for large specials. 12" x 4" blow-offs smallest. The large specials were almost invariably good. Some trouble to get clean perfect 12" and 16" specials.						
62–67	From iron used in small specials and jobbing work. A few 48" curves and sleeves also cast from it. Specials were very good and iron in small specials seemed strong and close.						

Notes 1 to 9, see Sheet A.

TABLE II. Summary of Test Bar Tables and of Pipe Data—Condensed Largely From Table I.

Note: This table contains results of most of test bars and pipes cast for the M. W. W. at four large foundries, between April, 1896, and February, 1897. The pipes and bars are the same ones to be found in more detail in Table I.

Foundry.	Test bars. No. in Aver.	Test bars. Aver. of [1]Corrected Loads. lbs.	Test bars. Aver. of [1]Corr. rect'd Defl. inch.	Size and Class of Pipes.	Range of Thickness. inch.	No. of Pipes Cast.	No. [2]Rejected	% Rejected	No. Cut.	% Cut.	No. Shipped.	No. [3]Split	% [4]Split	No. Burst in Proving.	% [4]Bur't	[7]Condition of Pipes when Flasks were Removed.	[7]Time left in Flask. (Approximate.)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
									LARGE PIPES.								
X B	678	2150	.346	48″ A, B & C	1.15 to 1.40	2760	365	13.2	155	5.6	2395	15	0.6	2	.08	Cool.	Overnight.
Y 2	203	2030	.349	48″ B & C, 36″ B & C.	1.03 " 1.40	1875	75	4.0	100	5.3	1800	11	0.6	2	.11	Mostly black hot— A few cool.	About 3 hours— A few overnight.
Z	861	2310	.420	48″ B & C, 36″ D 30″ D & E.	1.10 " 1.40	2215	90	4.1	55	2.5	2125	10	0.5	2	.09	48″ and 36″ black hot; [8]30″ mostly red hot.	About 3 hours; About 2 hours.
Q	665	2065	.366	48″ A & B, 42″ B & C, 36″ B	1.03 " 1.25	1835	395	21.5	65	3.5	1440	18	1.3	4	.22	Mostly black hot.	About 3 hours— A few overnight.
									SMALLER PIPES.								
X N	127	2085	.367	16″ D & E	.75 to .81	1275	[5]170	13.3	0	0	975	97	10.0	0	.0	Mostly red hot.	About 1 to 1½ hours.
X S	64	2280	.353	12″ B & D, 16″ B.	.57 " .65	555	[6]165	29.8	0	0	380	29	7.7	2	.5	" " "	About 1 hour.
Y 2	203	2030	.349	20″ C & D, 24″ C.	.79 " .87	570	30	5.3	40	7.0	540	5	0.9	2	.4	Nearly all black hot.	About 1 to 1½ hours.
Z	473	2285	.418	16″ D, 20″ D & E.	.75 " .92	1895	95	5.0	10	0.5	1800	103	5.7	0	.0	[8]Mostly red hot.	" " " " "

[1]Bars are 24″ span and approximately 2″ wide by 1″ deep. Results corrected for variations from 2″ x 1″, as follows: $\text{Cor. Load} = \dfrac{\text{Observed Load}}{\tfrac{1}{2}\text{ measured width} \times \text{sq. of thickness}}$ Corrected Deflection = Observed Deflection × measured thickness. [2]Rejected for all causes but test bars. [3]Split from time of casting until laid—Nearly all these pipes are now in the ground. The majority of split pipes were found split at end of the journey from foundry to pipe yard. About 15 of the large and about 30 of the smaller pipes were split in teaming from pipe yard to place of laying. The numbers of split pipes above given are probably somewhat too small, as the formal records of split pipes are somewhat incomplete. [4]% split and % burst are figured not on number cast but on number shipped, which is more nearly correct for the purpose. [5]Nearly one-half of these rejected for wrong dimensions. Also 137, *not included* above, rejected for deficient test bars. [6]About one-half of these rejected for wrong dimensions; also 13 *not included* above were rejected for weak test bars. Moreover, *included* in the 165 are 3 ladings of 13 pipes each, rejected for "hard, brittle iron"—test bars with one of these ladings were 1710—.275 and 1795—.294; test bars with the other two ladings were not much below the average. [7]Information on foundry X from writer's observation; on other foundries, from inspectors, corroborated by writer's partial observation in case of foundry Y. Core spindles of all pipes are removed while iron is red, but the earth remains inside the pipes until cut out when the pipes are cleaned. [8]30″ & 20″ pipes of this foundry are, however, allowed to stand in the pit, *with sand adhering*, after flask is removed, till black hot.

THE RISE AND FALL OF THE AMERICAN MERCHANT MARINE.

By Joseph R. Oldham, C.E., N.A.

[Read before the Civil Engineers' Club of Cleveland, February 28, 1899.*]

Although for the sake of brevity I have given my paper a general title, the following remarks and statistics refer particularly to the foreign trade, for I opine that few of our community need have much anxiety concerning our lake, coasting and river trade, as these are able to take care of themselves. Hence there is no fall to chronicle in their case.

As regards our foreign trade, the tables supplied by the Commissioner of Navigation do not carry us farther back than 1857, at which date our total merchant marine was practically half a million tons. This tonnage continued to increase up to the year 1861, a very interesting date, no doubt, to many in this room, at which time our total tonnage was 5,539,813 tons. The British tonnage was then 4,806,826 tons (average size of vessel only 171 tons). Notwithstanding the marvelous increase in our lake trade and coasting tonnage, our merchant marine has steadily declined since 1861. At that time the registered American vessels employed in the foreign trade amounted to 2,496,894 tons. The average size of vessel at that precise date I cannot quote, but it was nearly 500 tons, for in 1868 the average capacity of our foreign ships was 485 tons each. I can well remember the splendid American packet ships of those days; for, being the assistant to the chief engineer to the Bureau Veritas, it was my good fortune to be brought in touch with the masters and officers of those fine, swift vessels,—such, for instance, as the "Young America," "Flying Cloud" or "Red Jacket,"—and often have I heard

> Ten jolly tars, with musical Joe,
> Heave the anchor apeak, singing "Yo, heave ho!"

In looking back to those times it seems as if some gigantic calamity had stricken our foreign-going ships, and, indeed, the seeming is not far from the real, for, in addition to the disturbing element of civil war on our side, there was an equally disturbing mechanical element acting against us, in the inauguration, by our European friends, of screw propulsion for the ocean trade, which began to be generally adopted on the Atlantic about the year 1860.

When our Civil War broke out, the enterprise and ingenuity

*Manuscript received April 10, 1899.—Secretary, Ass'n of Eng. Socs.

of American merchants had reached its zenith and had risen to an altitude never before approached in so short a time, but be it remembered that up to that epoch the science of iron construction was in its infancy, and what I may designate as efficient screw tramp steamers were not yet developed.

In 1850 the United States added over 272,000 tons to her merchant marine. The tonnage added by Great Britain and other nations together, in the same time, was only 217,000 tons. It is interesting to relate that, in our trade with Great Britain, the American tonnage entered and cleared in those days was practically two and a half times as great as the British tonnage; but, as soon thereafter as 1867, their tonnage in the North Atlantic trade was three times as great as ours, a marvelous change to their advantage. Still, that was only an initiatory step of an expanding movement that was to be twenty times as large as ours, and to equal seventy per cent. of the total ocean trade of the earth.

I trust I have made fairly clear to you, in a general way, the extent of the *rise* of our merchant marine. Permit me, now, to refer to its fall, and to illustrate the salient features which have contributed to its decay. It was about this time that the Inman Company began to place large iron screw steamers in the North Atlantic trade. Of course these vessels would be considered small for such a trade to-day. I remember the "City of Limerick" well, but the one I had most to do with was the old "City of Baltimore." She was about 300 feet long and her speed was about 14 knots an hour. The Cunard Company, at this time, had the fine old side-wheeler, "Persia," 390 feet in length, carrrying the American mails. The "President" and "Pacific," of the Collin's line, were gone, and we had not, and did not have till the "Ohio" and "Pennsylvania" were built in Philadelphia in 1873, a single screw steamer in the North Atlantic trade. By North Atlantic trade I mean anything above 37.30 north latitude. We then had to import iron and also pay dearly for labor, so we were not in a position to build and operate successfully iron steamers to carry our own mails, and no one would then have thought of building an iron tramp, unless a handsome subsidy had been available. Hence the conditions were ripe for the decline of our merchant marine employed in the foreign trade. I have referred to iron screw steamers, and to side-wheelers also, but I have not attempted to show the economy of screw propulsion (which was adopted in 1840) over propulsion by side wheels with feathering floats, because I do not believe that the supposed or actual economy of screw propelled vessels over side-wheelers is due to the propeller.

I state this while thoroughly cognizant of the experimental fact that the slip of the side wheel is frequently double that of the screw, or as 20 per cent. is to 10 per cent. As regards slip, I would say that a medium slip results in no greater loss than a negative slip does in gain. "As a propelling instrument the side wheel is not inferior to the screw," but its speed of revolution is necessarily slow, and side-wheel engines are therefore larger, costlier and heavier than screw engines of the same power. As an illustration, the engines of war vessels develop much greater power when working at their maximum than engines of similar cylinder area in the mercantile marine. This is usually due to greater speed of revolution, and I need hardly remind you that when the speed of a steamer's engines at sea is doubled the power is doubled. If this be so, does it not appear that the economy in coal consumption, which certainly followed the introduction of the screw propeller in ocean steamers, should be attributed to the higher efficiency in working of the steam engines rather than to the propelling instruments? A word about twin screws connected to independent engines, and I have done with this part of my subject. These were adopted by Mr. Dudgeon in 1861, and as early as 1868 were fitted on these lakes to the iron steamer "Philadelphia," of the Anchor Line, at Buffalo, N. Y. Although I admit the necessity for twin-screw engines in vessels of large power, say such as would require a screw shaft of 20 inches in diameter, or over, and in war ships, I maintain generally and presumably—keeping the above exceptions in mind—that there are but two highly efficient types of propulsion,—viz, side wheels for working in a shallow water trade and a single screw for deep water cargo steamers. The necessity for duplicate screws in war vessels needs no comment.

Permit me, for a moment, to draw your attention to one of the first steamboats that visited us from abroad.

The first steamer that ever ploughed the mighty waves of the Pacific Ocean was only as large as the Cleveland tugboat "Harvey D. Goulder," and yet that little vessel traversed some 13,000 miles over two oceans, and then became of inestimable value to the gold seekers of 1845.

The "Beaver" was only 101 feet by 20 feet by 11½ feet; yet, sixty years ago, she made a safe voyage from London to Astoria, Oregon.

The progress in shipbuilding and in marine engineering during the last half of the present century has been, perhaps, more gradual and tentative than is apparent to the casual observer of to-day. In confirmation of this I shall endeavor to point out the

most clearly defined steps in the development of the magnificent specimens of naval architecture to be seen in our seaports at this time. One of the early steamers, of about the same principal dimensions as the celebrated "Great Britain," could barely carry sufficient fuel for a voyage from New York to Melbourne at a rate of speed in smooth water of about ten miles per hour, as this distance could not then have been steamed with less than 4500 tons of fuel. So I will call the dead-weight ability of such a steamer 4500 tons, all of which would be fuel. The change from wood to iron (which commenced about 1840 and became general about 1855) effected, or made possible, an increase in dead-weight ability in ships of like external dimensions—on account of the reduced weight of material entering into the construction of the hull—of fully 20 per cent., so that a ship of 4500 tons burden would carry fully 5000 tons when iron took the place of oak. The actual gain, however, was more than this, for, while the hull was lighter with the same load displacement, it was of still greater internal capacity, and consequently could carry over 20 per cent. more of light goods, such as tea, or cotton, as then stowed. So this change made the exemplary vessel capable of carrying about 600 tons of cargo in addition to her fuel.

Surface condensation became general about the year A.D. 1850, though the principle was patented by Samuel Hall in 1838. This reduced the coal consumption fully 15 per cent. By this step the steamer capable of carrying 4500 tons of bunker coal at the rate of ten miles per hour would have her coal consumption reduced from about 70 tons per day to 60 tons, which on a voyage, say from New York to Melbourne, would leave a further capacity for cargo of about 675 tons; then 600 tons saved in weight of hull and 675 tons saved in bunker coals by surface condensation equal 1275 tons rendered available for cargo by these improvements. The monetary saving by this reduced consumption of fuel may not have been very large, but the cargo capacity gained, and the time and labor saved in handling only 3825 tons instead of 4500 tons, would probably amount to a saving of 5 per cent. of the total cost of the voyage. The following narrative may serve to illustrate the importance of surface condensation.

In the year 1825 the merchants of Calcutta offered a premium of a lac of rupees, which is equal to about $750,000, for the first voyage of a steamer to India and return averaging seventy days each way. This offer brought out the side-wheel steamer "Enterprise," of 470 tons, and with engines of 120 horse power. Her entire cargo consisted of fuel and stores for an expected run of

thirty days to the Cape, a distance of about 6100 miles. The actual time occupied by the voyage out amounted to one hundred and fourteen days, forty of which were under sail and eleven at anchor. The average speed was five knots an hour. The poor showing of this experiment was almost entirely due to the lack of a surface condenser. Although the speed did not approach that stipulated, the master, Lieutenant Johnstone, R. N., received a present of $50,000 for his arduous services.

Compound screw engines with increased pressure of steam, adopted in 1854, became general about the close of our Civil War. By this improvement, when the steam rose to 60 pounds, the saving in coal consumption amounted to fully 30 per cent.

In the year 1874 the triple expansion system was devised by Dr. Kirk and fitted in the steamship "Propontis," but the Rowan boiler failed and the multiple expansion system received a setback. Four years after this date, however, it was again taken in hand by Alexander Taylor, of Newcastle-upon-Tyne, and was fitted in the steamship "Isa."

As economy in construction, as well as in propulsion, was a potent factor in building up the rivals of our mercantile marine, I trust I may be excused if I touch on the cost of construction. Forty years ago as much as $200 per ton was paid in London for the steel with which to build a steamer. Though there is to-day a smaller amount of manual labor represented in a completed ton-weight of a factory or bridge or ship, the relative amount of manual labor, say per ton-weight of material, has not largely varied during any length of time for many years.

In the early days of iron shipbuilding I can well remember that the cost of the iron was about one-third of the total cost of the finished ironwork in the hull, and to-day it is about the same. Steel costs about 1¼ cents per pound throughout a ship, or nearly so, and the labor costs about 2½ cents. Thus the former is one-third and the latter two-thirds of the finished structure. Heavy ships may now be built for 3½ cents per pound, but the ratio of cost of labor to the cost of steel does not appreciably vary from the foregoing. In 1878 mild steel was adopted on the Tyne as a substitute for iron in the construction of ships. The effect of this was to augment by about 15 per cent. the carrying power of ships of the same load displacement without loss of strength, as mild steel has about 50 per cent. greater tensile strength than iron. It was not, however, until three or four years later that steel was generally used in the construction of ships. This improvement increased by about 375 tons the dead-weight ability of such a steamer as we are

now considering. (Possibly before the present century closes we shall find a shipowner with sufficient enterprise such as shown by Mr. Henry Clapham, of Newcastle-upon-Tyne, who built the first purely cargo steamer of steel in 1880, to build a ship of nickel steel or other similarly light metal of equal or greater tenacity.) The gain in dead-weight ability by this final step in ship construction would be about 300 tons.

In 1881 multiple expansion engines were started on their onward career by adoption in the steamship "Aberdeen" by R. Napier & Sons. By this system, coupled with improved models and greater efficiency in boilers, augmented piston speed and improvements in feeding and lubricating, the coal consumption has been reduced fully 33 per cent. This would seem to show that about fifty years ago the largest and best steamer afloat could hardly carry sufficient bunker coal to steam from London to Calcutta (about 8000 miles) at an average speed of ten miles per hour even without a ton of cargo on board. To-day, thanks to the higher efficiency of hull, boilers and machinery, if coal could not be obtained on the voyage, a steamer of the same general dimensions as the one referred to could carry fully 4000 gross tons cargo and sufficient bunker coals to steam from London to Melbourne (about 12,000 miles). Indeed, this would not be considered an example of extremely high efficiency in the year 1899.

To summarize, I may say that during the last fifty years steam pressures have gone up from 9 pounds to 300 pounds per square inch,—indeed, I have seen several marine engines working at a pressure of 400 pounds per square inch; piston speeds have risen from 200 feet to 1200 feet per minute. The weight of machinery per horse power has fallen from about 1000 pounds to 200 pounds, and even less; and the coal consumption has been reduced from about 9 pounds to 1 pound per hour per indicated horse power.

Now, taking as an example a steamer such as mentioned, built about fifty years ago, it will be found that all her capacity was required for fuel for a voyage of sixty-four days at ten miles per hour. The steps or gradations towards efficiency in cargo carrying and steaming may be summarized as follows:

1840—To general change from oak to iron hulls effected an increase in dead-weight ability in a steamer 300 x 51 x 29 feet of 600 tons.

1854—To surface condensation lessened the amount of coal required 15 per cent., or 675 tons.

1860—To compound engines, operated by Scotch boilers, lessened the coal required by 30 per cent., or 1147 tons.

1878—To mild steel displaced iron, and increased the carrying capacity 15 per cent., or 375 tons.

1881—To triple expansion, augmented piston speeds, with higher pressure, reduced the fuel required by fully 38 per cent. This in the foregoing example amounts to 883 tons.

1898—To saving in fuel due to quadruple expansion, improved boilers, feed heaters, etc., 33 per cent., or 520 tons.

1899—To gain in dead-weight carrying capacity during the last half of this century, 4200 tons.

In attempting to apportion the precise amount of gain or advancement due to the adoption of stronger materials or improved types of machinery, permit me to point out that, though the increased efficiency attributed to inventions of a certain decade is mainly due to the improvements named, there are, of course, other causes contributory to the general progress. For instance, when iron superseded oak in ship construction certain so-called adornments and superfluous appendages to the hull and equipment were simultaneously dispensed with. When steel was adopted in lieu of iron for shipbuilding purposes the scientific principles of naval architecture were being extensively investigated and demonstrated. Prior to this period the decks and top sides of ships were lamentably deficient in strength. The bottom, per unit of surface, was twice or three times as heavy as the sides, and could resist a bending moment ten times greater than the deck could withstand. So much more solid material was worked into what I will call the bottom flange than into the top flange of the girder that the neutral axis was frequently 80 per cent. of the total depth below the gunwale, while nowadays it seldom exceeds 60 per cent. I referred to and illustrated this some seven years ago in connection with three Anchor Line boats built under my superintendence.

With regard to the engines, when the two-step compound superseded the single expansion condensing engines the piston speeds were augmented as the pressures rose. In those days of low pressures and velocities there was no better way of doubling the power of an engine than by making an engine of the same size work at double the speed with improved boilers.

In looking at the most perfect steamship of to-day one is led to wonder why she was so long in coming, and to whom the credit is at length due for her appearing. The only reason I can give for the apparent delay is that a multitude of agencies were necessary to the final effect, and of these the most important is time. Perhaps it would be as difficult to give a full and exact answer to the latter query as to the former, for it is questionable whether more honor

is due to the skilled naval architect or master of engineering, who designs and delineates the great battle ships or greater mail steamers (with rich stores of mechanical science and experimental data to draw from), or to the untutored denizen of the river bank who first dug out the light and graceful canoe or formed the delicate frame of the coracle.

Now that the initiatory steps have been taken towards the construction of a large and deep waterway to the Atlantic Ocean, our lake shipbuilders, shipowners and merchants will probably realize as they have never done before the absolute necessity for some such measure as that proposed by Senator Hanna for creating a large modern mercantile marine. But we are even now in a position to contract with Europeans for steamers carrying from 2000 to 3000 tons, and the average tramp does not carry more than 2500 tons. Moreover, if we can build and export these vessels for as little as they cost in England what would be the use of a free ship measure? I use advisedly the expression "creating," for please bear in mind that at present we have no modern cargo steamers employed in a general foreign trade. The British have many million tons of high-class "tramp" steamers.

With 10,000 miles of the finest seacoast in the world, with the richest stores of iron, coal, copper and wood, with the most bountiful grain and cotton fields, with the greatest and most efficient railroad system on earth, with 75,000,000 of a population, comprising the most intelligent, energetic and intrepid of the Anglo-Saxon race, with our inventive skill and enterprising faculties, such as no other people possess, we succeeded in producing 62,000 tons of steel shipping last year. The British shipbuilding yards turned out not less than 1,500,000 tons in the same time. Indeed, three single British shipbuilders each launch more steel tonnage than we do over our whole coast. For example, Gray, of Hartpool, built 72,323 tons last year; my old friend, G. B. Hunter, of the Tyne, built 68,696 tons; Messrs. Harland & Wolff, of Belfast, built 67,905 tons. In 1897 the latter firm constructed the enormous amount of 84,240 tons.

Nothing is further from my desire than to say anything that would belittle or minimize the enterprise and grand achievements of our shipbuilders and engineers, but when matters have reached their worst the actual facts may as well be known by us; and nothing could well be worse than the figures given in the latest report issued by the Commissioner of Navigation. In that report, on our foreign carrying trade, he shows that American vessels carried only 25 per cent. of our imports and exports in 1886, and now they carry

less,—viz, 23 per cent.,—while the foreigners' trade has jumped up from 75 to 77 per cent.

Just before our Civil War,—viz, in 1860,—American vessels carried 71 per cent. and foreign vessels 29 per cent. of our imports and exports. I am inclined to the opinion that there is a more or less general impression among those unassociated with shipping that the former deplorable percentages represent our normal condition; that we never were a comparatively great maritime people, and that therefore we should be content to develop our railroads, work our mines, produce our crops, etc., without providing marine transportation, even for our own exports. But such is far from the truth. What we are now endeavoring to attain is only our old status in the shipping world. Just before our Civil War we had a greater ship tonnage than any other nation on earth, and with regard to shipbuilding we then constructed more than the British did. The figures for 1861 were British 208,326 tons *vs.* American 233,194 tons. In 1860 we were adding more tonnage to our mercantile marine than all the rest of the world put together. Last year our "Soo" canal trade exceeded eighteen and a half million tons. These facts should encourage our legislators and others to work for the rehabilitation of our shipping, and how this can be accomplished with as little expenditure and as little loss of valuable time as by enacting Senator Hanna's shipping bill, S. 5024, I have yet to learn or hear suggested.

While that bill is heartily indorsed by those who have studied and realized the degraded condition of our foreign shipping trade, there are some who seem to think that the rehabilitation of our merchant marine is a matter that concerns the maritime community only; whereas it has been clearly demonstrated time and again that the national merchant ships contribute more wealth and provide more general employment to the masses of the people producing and operating them than any other structures of similar bulk or weight.

Let me quote you from a report just issued by the Cairn Steamship Company of one year's work. The net profit of operating six small foreign tramp steamers was $115,000. After deducting interest, directors' remuneration, income tax, auditor's fees and part formation expenses there was a balance of over $108,000. The directors recommended a dividend at the rate of 14½ per cent. per annum. The sum of over $56,000 has been written off for depreciation. The chairman added that out of six vessels, of which the fleet consisted, four had been cleared off for one-third of their original value by the surplus of profits over 6 per cent. The fifth

vessel was also very nearly paid off. Mr. John Price, the chairman of the Cairn Company, is a shipbuilder by trade, and had no early training in the way of managing a steamship company, for prior to his becoming general manager of Palmer's Shipbuilding Company he and the writer were for several years engaged in the same office classing vessels; hence I can speak with confidence of the statements he makes.

It is not the construction of ships that keeps us back, or rather it need not keep us back for the future. But the accommodations for officers and crew on an American steamer are more commodious and better furnished, and the owners find bed and bedding for the men. These conditions all add to the first cost of an American ship, and also to the cost of insurance. It may be true that if tenders were asked to-day for a steamer from our shipbuilders and from those in Europe the latter might be the lower, but then the British alone have over one hundred large steel shipbuilding yards, the average output of each being 15,000 tons per annum. We have twenty large steel shipbuilding yards in the whole of this country, the average output of which was 3000 tons each last year; so we have not the competition or steady work, and without constant employment shipbuilders cannot work economically. This state of affairs cannot be improved without assistance or "compensation" for an initial loss for some years to come, but it is mainly in operating our foreign-going steamers that we are at a great disadvantage. Money is dearer here; higher wages are demanded by seamen. American ship chandlers and others who supply and operate ships charge more than foreigners. Then, the French especially, have so manipulated the international tonnage law that their steamers are worked on a much smaller register, or official tonnage, than ours, and the men, though not paid nearly as high wages as American sailors, are poorly found. The masters get about 30 cents per man per day and "starve the men," as sailors say. Still it is no uncommon thing for the engine room staff of a tramp to retube a boiler while detained in a foreign port and thoroughly overhaul the engines, even to the fitting of a spare crank shaft, without assistance from a shop, especially if there happens to be none at the port.

As regards French commerce, our trade with that nation appears so small that they do not mention America among the six great maritime nations. The principal foreign flags which participated in the French maritime trade in 1897 and the proportionate share taken by each is as follows: British, 41 per cent.; German, 6.3 per cent.; Spanish, 3.7 per cent.; Dutch, 2.8 per cent.; Norwegian, 2.3 per cent.; Italian, 1.9 per cent.

Let the American shipowner be compensated so as to be on an equality with the foreign shipowner, and I venture to prophesy that long before twenty years expire we shall see more than one hundred large steel shipbuilding and marine engineering establishments on the coasts and lakes of this country, turning out, as others are now doing, one hundred million dollars' worth of steamship tonnage per annum.

I intended to write out a detailed comparison of the expense of working a modern American tramp steamer with the actual cost of an ordinary British tramp, but, after tabulating the schedule of the latter, I remembered that there was no such thing in existence as a modern American tramp from which to tabulate average expenses. Mail steamers or regular liners in the coasting trade are not the type of vessel out of which the foreigner makes the money and acquires the balance of trade in his favor. These expensive steamers do not pay as a rule. I think the Cunard seldom pay more than 2 per cent. per annum, and frequently they pay no dividend. But the Newcastle and Sunderland tramps commonly earn from 15 to 25 per cent.

Now, with no Suez Canal trade, with American vessels carrying only about 9 per cent. of our American imports and exports, and without a single modern tramp on the ocean, it is surely time to provide compensation of some kind to rehabilitate our merchant marine. The want of an American merchant marine appears to retard our export trade, for the chairman of the West of Scotland Steel Institute spoke as follows last month:

"The only circumstances which have prevented American steel from competing with the British article more than it has done have been that high freights have been ruling from the other side. When these freights are reduced I understand that large quantities of steel will be exported" (from America).

Now, with reasonable compensation, American steamers could carry our steel and other products at reduced rates of freight to all parts of the world, and thus increase our export trade.

Gentlemen, I have referred to a time that was ripe for the decay of our merchant marine. In conclusion, let me assure you that the time is now equally ripe for its revival, and if that can be realized by this mighty and enterprising nation our harvest of the seas for the future will surely be rich, plentiful and abiding.

DISCUSSION.

THE CHAIR.—This is one of the most interesting papers I have heard for a long time, and I would be glad to hear from any of the members.

Prof. C. S. Howe.—What is the comparative cost of constructing an American tramp and an English one, and, if we had such, could they afford to pay any dividend under the present conditions?

Mr. Oldham.—Until the late rise in the price of steel, which has gone up about 50 per cent. I believe, there was very little difference between the cost of the same class of tramp here and in the old country, but we cannot build as economically unless we have a regular trade. Our shipyards are idle for one-fourth of the year, but if we had constant employment, which can only be obtained by remunerating the shipowner for some time, this could be accomplished. When the state of affairs becomes normal we can build hulls cheaper than they can in the old country; and after our brokers become accustomed to lower profits, and when we have a better consular service, we might have an American ship as cheaply built as a British ship; but if we go to a foreign port we find that there is no one to look after our interests, and the ship might have to lie for weeks without a charter. That is where the loss comes in. It is generally foreign trade that pays. We can build ships with equal accommodations with the English, but our men are accustomed to better accommodations. These will have to be reduced, and I am afraid the living will also have to be reduced. Senator Hanna suggests a good way to compensate the shipowners.

Mr. B. L. Green.—What is covered by the $3\frac{1}{2}$ cents per pound; does it cover simply the steel work of the vessel? Also, what is the most economical tonnage for a tramp steamer? Is it about 5000 tons, and does the construction per pound of tonnage decrease or increase beyond that tonnage? Will great vessels come into freight service? Is your table of comparative tonnage comparable with the report of the Maritime Congress of Paris?

Mr. Oldham.—The $3\frac{1}{2}$ cents refers only to the hull; it is the cost of the steel and the working of the steel into the ship. About 6000 tons is a fair average, although some are as high as 12,000 tons. The cost of construction becomes lower per ton as the size increases. I think the "Oceanic" will cost less per ton than smaller ships. I do not remember much about the French maritime report.

Mr. Green.—Is there something, as regards peculiar subsidies, which makes it easier for a vessel hailing from England to do business than one from the United States?

Mr. Oldham.—It is altogether false that the steamers are assisted by the Government. They are harassed by the Government. The British mercantile marine receives no assistance from the Government except that of an excellent consular service. As for the mail steamers, they receive a big subsidy for mails, but this

is to compensate them for delays. Mail steamers sometimes have to wait a half-day at Queenstown, in crossing the Atlantic, waiting for the mails.

Mr. J. N. Culley.—What is a tramp steamer?

Mr. Oldham.—It is a steamer which takes a charter to go anywhere. It is not a regular liner in any way.

Mr. W. H. Searles.—It is rather humiliating to perceive that the tonnage of the United States has declined for so many years and to so great an extent while the tonnage of the world has been rapidly expanding. The weight of sea-borne commerce has increased eightfold in the last fifty years, and the best authorities on this subject predict that it will at least double itself in the next fifty years. If we expect to enjoy any reasonable share of this enormous traffic it is high time that we bestir ourselves. The average size of steamships is also constantly increasing. The old "Great Eastern" of 1860 was thought a monster in that day, yet now a regular liner is building which greatly exceeds it in every particular. The larger the vessel the greater is the economy of transportation, and the only limitation in size at present is found in the ports and channels which the steamers must use. Liverpool, after having repeatedly enlarged its facilities to accommodate the increasing size of steamships, is now widening and deepening its docks to accommodate vessels up to 900 feet in length, 90 feet in beam and 36 feet in draft, and is expending at present $17,000,000 on these enlargements.

Improvements in progress on this side the Atlantic will give a low tide channel of 30 feet to Philadelphia and Boston and Galveston, and of 35 feet at New Orleans and New York.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXII. JUNE, 1899. No. 6.

THE PRODUCTION OF SEAMLESS TUBING.

BY H. S. WILSON, MEMBER, ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, February 1, 1899.*]

THE first thing to consider in preparing to make seamless tubing is the kind and quality of the steel best adapted to the purpose. Up to within two years such steel could be obtained only in Sweden and Norway. The ore used is of two kinds, a very pure hematite and a rich carbonate, and the lime used, owing to its semi-Arctic origin, is very low in phosphorus.

It is absolutely necessary that the percentage of elements of phosphorus and sulphur be as low as possible. The sulphur in fact must be present only as a trace. The mines are situated nearly on the border between Norway and Sweden, and have been for years a source of immense revenue to both countries. The steel is there produced in open-hearth furnaces of about five tons capacity, and the processes are carried forward, as far as possible, with the use of charcoal as a fuel. I was unable to secure any of the charge weights at the blast furnace, but presume they are about the same as would be good practice here.

One of the facts developed is that metal of the right quality cannot be made in large hearths, about five tons or twelve thousand pounds being the limit. Apropos of this I will relate a circumstance occurring under my own observation. Among a lot of 500 tons of steel bought from one firm, through a New York agent, occurred one group of 200 bars. These bars being put to

*Manuscript received April 29, 1899.—Secretary, Ass'n of Eng. Socs.

our ordinary tests and analyses seemed all right. They also passed all the hot processes creditably, but the first piece that reached a cold drawing bench gave a yowl that woke up every one from the manager to the errand boy. As no thought of the steel being otherwise than good had occurred, the foreman of the annealing room received my immediate attention.

Repeated trials under my personal supervision brought no better results, and it was only by a graphic demonstration in the presence of the agent that I could convince him that the steel was not right. When the history of the steel was traced to its origin, it was found that it had been refined in a new furnace of American design having a capacity of fifteen tons.

A Pennsylvania firm made and sent us many samples for trial, but after a long series of failures they started in on the same basis which Swedish practice had proved to be efficient, dropping their American ideas of melting a whole mountain at one heat, and refined in a small furnace taking a change of 13,000 pounds.

The very first sample proved fully as good as the foreign make, except in tensile strength. For tubes of large diameter it even worked better. One of the finest lots of tubes that were produced were from this first lot of steel, and were for the inner barrels of the famous dynamite guns sent to Cuba.

The dimensions were,—outside, $3\frac{1}{2}$ inches; inside, $2\frac{1}{2}$ inches; length, 16 feet; carbon, .30; ultimate strength, 67,000 pounds; limit of elasticity, $22\frac{1}{2}$ per cent. Tests all made annealed.

Assuming that we have our material satisfactory, the hollow billet, or the "How do you get the hole in it?" problem comes next. Let us take the oldest methods and follow through the various changes in later use. The first Swedish billets were cast hollow, and then reduced in "fore and after" grooved mills.

These rolls were arranged with a beam for rolling on the rod and also for rolling off from the rod. By reference to the sketch you will note the position of the billet and bar in the before process. In this instance the rod or bar is placed in the hole first and the reduction made away from the beam, leaving the bar out of the hole when the pass is complete. This is all right when the tube or billet is thick and will hold its heat, but later when they get thin this would not do, as the rolling must be accomplished with considerable celerity to be successful. You will note in the after way, which is most common, the tube or billet is rolled on the bar and is removed by drawing the bar forward. A loose plug of high manganese steel furnishes the stationary medium for the inside diameter.

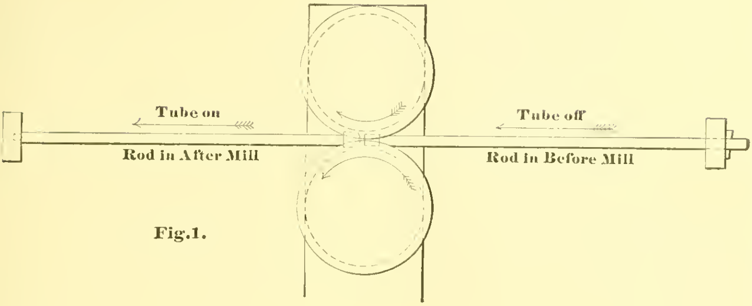


Fig.1.

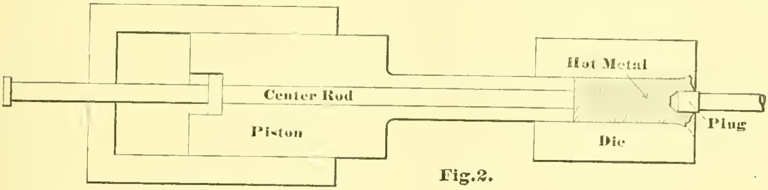


Fig.2.

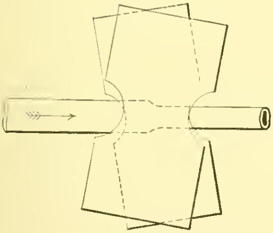


Fig.3.

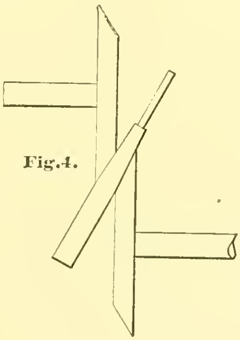


Fig.4.

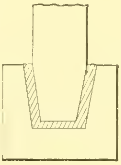


Fig.5.

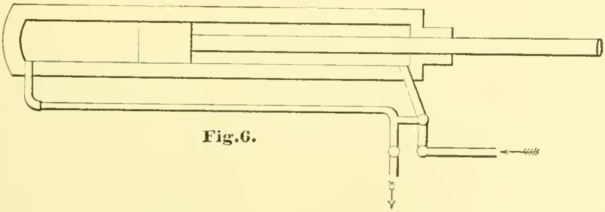


Fig.6.

As the ordinary billets come from Sweden they are of $3\frac{1}{2}$ inches outside diameter and $2\frac{3}{4}$ inside, varying in length from 10 inches to as many feet. The casting method being very expensive owing to imperfect casts and costs of molds and cores, recourse was had to some method of punching or piercing a hole through the solid ingot.

The oldest way consists in forcing a hexagon ingot 12 inches in diameter over a 6-inch mandrel. The machines are powerful hydraulic affairs. You will note from the sketch that the block of steel is forced out through a bell-shaped opening. The steel plug is loose and goes through and into a slight opening in the ram. There is an auxiliary plunger passing into the end of the main plunger, which at the proper moment allows the plug to be received, and then discharges it and the small "biscuit" of steel which has been punched out. The plug of course is somewhat larger than the bar or punch, which provides a safer clearance for the discharge of the pierced billet. All the further reductions are carried forward on the "fore and after" mill already described, and the billets are sawed hot to the proper length. Tubes called stock tubes can be had which are ready for the cold reduction processes. These tubes are from $2\frac{1}{2}$ to 2 inches diameter, and from 5 to 10 Birmingham gauge, weighing $17\frac{1}{2}$ to 35 pounds.

One of the most interesting processes is that of the Mannesmann Bros., which makes use of a curious phenomenon as well as the fact, that the weakest point in a bar of steel is at its center. The Mannesmanns did not invent this process, but discovered it.

They were trying to construct a mill for cold rolling steel, hoping by the arrangement of the rolls shown to roll a perfectly round straight bar. For this purpose the mill was a perfect success, and as the bars of rough steel were rather irregular the idea was developed of trying the method on hot work, which it was hoped would save one annealing of the stock and much wear on the finely finished concave rolls. At first, of course, the steel was secured only a fraction of an inch larger than wanted. Wishing some stock one day, much smaller than any on hand, they concluded to roll some down, and incidentally to see how much reduction could be made at a pass. The first pass produced a bar of steel with a hole entirely through it, and thus the so-called Mannesmann process became a fact. The phenomenon is explained by the tendency of masses of steel to remain weakest at the center, and also the fact that all the different molecules of the metal travel at a different velocity. You will note that the angular position of the rolls causes the bar to have both a rotating and longitudinal motion, the sum of the two producing a spiral.

Also the part which has passed through the rolls, owing to its smaller diameter, revolves faster than the larger portion, thus giving to the mass a wringing motion, causing the center to become separated and forming an opening, which in practice is enlarged slightly by holding a stationary bar against the end. After being pierced by this method, the billets are further reduced by a mill having a spiral in the opposite direction, and finally by an after mill as before explained.

A modification of this system is the so-called Stiefel process, in which exactly the same result is produced in a modified manner. I will state that this process was copied by Mr. Stiefel from one already in use in Sweden. You will observe that in this instance we have two slightly beveled disks and that the solid ingot passes through in a diagonal direction. Going further, note that the large diameter of one disk opposes the smaller circle of its fellow, and the result of this is to produce the identical wringing motion before noticed. Added to this is the high velocity of the moving parts, causing centrifugal force to assist in the operation. Use is made here also of a bar for smoothing out the inside of the hole.

Additional features consist of a pair of segmental rolls, having tapering grooves which, by a succession of squeezes, stretch the metal along a bar. As an illustration, you can compare this process to what would occur should you squeeze a piece of putty along your finger by the use of the other hand. After the metal has been extended it is afterwards stripped from the bar by a very heavy chain bench.

There are yet one or two more special processes of producing hollow billets. The one practiced at the works of the United States Projectile Company, in Brooklyn, deserves notice. In this method a short block of round steel is placed in a conical mold and a tapering plunger forced down into it, producing a cup-shaped piece, from which, by successive draws through dies and over mandrels, a $3\frac{1}{2}$-inch tube, closed at one end, is produced.

From this the tubes are sent to a hammer to have a square tag forged on the closed end, and the open end also has the ragged edges trimmed or cut off. After being further reduced by drawing hot through a succession of gradually decreasing dies to the usual size of $2\frac{1}{4}$ inches, they are ready for cold drawing. This all sounds very simple, but it is not. First, there is the hydraulic plant developing a pressure of 2500 pounds to the superficial inch, and driven by an engine of 1500 horse power. Then there is the material composing the dies, mandrels, taper plungers, etc. Quite an item to consider is the packing to stand any such pressure. I can only

touch briefly on these items, as to go into all the details would consume more time than I am allowed for this paper.

For the short tapering plungers in the initial operation nothing has been found to replace a good quality of gray iron. The conical die is also of the same material. For the longer mandrels, tool steel of rather low carbon gives the best result, a preference being given in favor of the alloys of chrome. The dies are cast in a special chill mold and are of a composition of cast steel, scrap gray iron and ferromanganese.

This material is about as hard as chilled iron and must be ground to a finish. It is customary to lubricate all the hot tools with a composition of black oil and graphite. I have forgotten to mention that a special stripper is placed just below the dies in the second operations.

In the working of nickel steel as carried out by the Pope Manufacturing Company, at their works in Hartford, Conn., the billets are secured by drawing a circular plate about 14 inches in diameter and 10 gauge, the process being exactly the same as making a cartridge shell, by a succession of draws from a primary cup about 8 inches in diameter, about one-tenth being included in each draw after the first.

We have now reached the point where our troubles are to begin, and one of the first as well as almost the last thing is the proper way to anneal. We can anneal with muffles, both sealed and unsealed. We can use the slow process and soak them or the quick process and cool them in the air. We can use the heat direct or we can radiate,—either reversing, direct, or reverberating.

We can use for fuel hard coal, soft coal, wood, gas, coke or oil with natural or forced draft either by steam or air, and lastly we can spoil more tubes right at this point than is usually conceded. As all the foregoing methods are in everyday use, I will briefly mention them in succession.

When this industry was in its infancy, all tubes were annealed in close circular muffles, bringing the whole to a good bright red and allowing to cool in the open air. Later they were soaked,—that is, put in a pit and allowed to cool very gradually.

One American method consists in filling the muffles with gas or any non-oxidizable substance which prevents scaling and the excessive use of acid in pickling. Pickling is even dispensed with, but with very doubtful results.

The English method as practiced in Coventry consists in making a very large furnace which is fired with producer gas, heat being developed very slowly, and the charge cooled to a black

before it is drawn. The tubes are quite soft and pickle quickly. At Shelby, Ohio; New Castle and Ellwood, Pennsylvania, the latter method is in use, with the exception that coal is the fuel.

In the open hearth annealing the very best results are realized at the works of the Projectile Company. By their system the tubes are laid out flat on a hearth only one high when thin, and two high when of large diameter and thick walls. The fuel is gas coal with forced air draft. The flame passes just above the tubes and radiates the heat required. To anneal a charge of $1\frac{1}{2}$-inch No. 16 takes only about 10 minutes. The tubes as soon as heated are thrown off the hearth into an iron truck kept in a closed lower compartment of the furnace, where they cool sufficiently before being drawn out. At one time they used oil as a fuel, but it imparts to the tubes a peculiar scale or coating very hard to remove in the pickle.

Having properly annealed the billets, we advance to the process of pickling. This is accomplished by immersing the tubes in lead-lined tubs containing a hot solution of sulphuric acid and water, about one of acid to thirty of water by weight. The proportions, however, are not important when the bath is new, but when it becomes impregnated with iron more strength is required.

After a period of from ten to twenty-five minutes the tubes are found to be of a uniform dull gray and are then washed and dried. This drying is the important feature in the whole process. Unless it is done many tubes cannot be drawn, and furthermore the temperature at which the drying is carried on is of vast importance.

It must be that which will boil sulphuric acid, or a little below 400° Fahrenheit. At this stage is reached the place where we will either make a great noise over a failure or keep very quiet over success. If the tubes are not soft they will surely break or destroy the tools. If not properly dried they will wail their objections to the whole thing, giving off a series of grunts and howls that can only be appreciated when heard.

Supposing, however, that all has been right to this point, let us consider the machinery and tools employed in cold drawing as well as the *modus operandi* and the proper reductions to produce success.

First, of course, come the benches. When Mr. Stephen Truemann was imported to this country by Mr. Losier, he naturally built an English mill at Shelby, Ohio. Here are to be seen in long lines more than a hundred heavy chain benches traveling at a speed of from $15\frac{1}{2}$ to 20 feet per minute, with tongs for gripping the tube, die block and tail piece for holding the rods. The illus-

tration will, I hope, make the matter clear. The tube is placed on the rod and then the end stuck through the die, the tongs hooked in and the tube pulled between the stationary end of the mandrel and the die, reducing both the diameter of the tube and the thickness of the walls.

I have in the foregoing neglected to state that the tubes are first oiled by immersing in a tank of black oil and drained off by setting them on the open end. The principal constituent of this oil is the so-called oil asphalt,—a residue from the refining of illuminating oil. I have to show you only two samples, one a finished piece of tubing and the other a section, showing the exact effect of the drawing process. You will observe by the use of the micrometer the reduction in thickness between the two ends of the larger sample. To produce a piece of $1\frac{1}{8}$-inch No. 22 tube requires the following reductions, the annealing and pickling coming between each draw:

At the point marked with the heavy line the tubes must be cut in two and retagged, or rather they must be cut to weight, which in this instance is 5 pounds, producing when finished about 15 feet of tubing.

TUBES.

Dimensions of billet $2\frac{1}{4}$ or 2.250 inches, and the two walls equaling .350.

	Die.	Plug.	Walls.
First pass	2.12	1.87	.250
Second pass	2.04	1.84	.200
Third pass	1.97	1.81	.160
Fourth pass	1.90	1.77	.130
Sink	1.80		
Fifth pass	1.76	1.63	.130
Finishing	1.62	1.59	.130
	1.666	1.55	.116
	1.608	1.51	.098
	1.554	1.47	.084
	1.500	1.43	.070
	1.454	1.39	.064
Sink		1.35	
	1.314	1.25	.064
	1.266	1.21	.056
Lime—sink		1.16	
Finish draw	1.125	1.061	.056

You will note in the table of reductions the words "sink" and "lime." By sink is meant the reducing of the outside diameter, only made necessary in order that the finish draw may produce a tube of exact diameter and thickness. Lime is intended to indicate to the pickler that the tubes must be limed or washed in lime-water after pickling.

The application of lime prevents the formation of iron peroxide, which would leave the tubes a very dark brown or nearly black. In drawing the tubes cold care must be taken not to do

too much sinking, which produces a rough interior and a tendency to split or crack along their length. This is one of the reasons why tubes of small diameter and thick gauge so frequently split in working. As it is not practical to use a rod of less than $\frac{3}{8}$-inch diameter, the sizes must be reduced only from the outside, entailing much care in both the annealing and drawing.

When the rods are of tool steel and all is well the tubes slide through the dies with the greatest ease, but sometimes they do not,—they break; they scratch; they chatter, causing a succession of ridges along the tube, and in fact they sometimes have moods, when patience to overcome the difficulties is more than a virtue.

Breaking may be the result of inequalities of density traced to careless annealing, or they may have been heated too hot, which changes the nature of the steel. Also the rod may stretch, and it is rather a strange thing to see for the first time a $1\frac{1}{2}$-inch steel rod stretch out like a rubber band.

Scratching both inside and outside is the result of improper tools. The dies for roughing are best made of composition, principally ferromanganese, softened or toned with gray iron and steel.

For the drawing dies for finishing, a medium grade of chrome steel will answer. These dies and plugs are made as hard as fire and water will produce, using as a quench a solution of rock salt and water containing about 5 per cent. of sulphuric acid. Most hardeners use cyanide to protect the surface and a gas furnace in which to heat. The shape of the dies makes some difference also in the result.

One way is to use a die whose working surface is part of a circle. This form is short-lived and productive of mixed lots of tubes; that is, the tubes will vary much both in diameter and thickness. My own experience is that a parabola produces more uniform results than any other form of working surface. In order to render an exact adjustment, the plugs are made about $1\frac{1}{2}$ inch in length of working surface, and are tapered from three to five-thousandths in their length. All the tools must be constantly watched and cleaned, and so severe is the strain or pressure that, notwithstanding their hardness, small particles of metal will adhere so firmly as to require filing for their removal. Chattering may result from one of two causes,—too elastic rods or the presence of free acid on the surface of the metal. The remedy for the first is stiffer rods, and for the latter another baking in the dry oven. There are a number of variations to be spoken of in the line of cold drawing. There are several methods of lubrication. You can draw tubes with soft soap, to which has been added a little free

animal fat. You can also lubricate them with flour paste, containing a large percentage of tallow.

Both of the latter ways do away with drying the tubes. Neither of them, however, are as rapid as the oil system, requiring dry tubes for success. At the Projectile Company we used hydraulic benches, operated by means of differential cylinders, and I think it will be interesting to some to explain the details of the differential bench. First, you will note that the piston rod is nearly half the area of the cylinder. Next observe that the valves are arranged for three positions. First, pressure cut off from either end; second, pressure on both ends and the exhaust closed, and third, pressure at the front, with exhaust open.

Thus in use, to cause the bench to travel away from the die, the third position is operative. To return the bench or tongs to the starting point the exhaust is closed and pressure turned on both ends of the cylinder, in which case the difference in area between the two ends will cause the piston to travel away from the greatest pressure and towards the less resistance.

This motion or differential action is what gives the machine its name. There is a great saving of power, as the piston makes one round trip, with only one cylinder full of water. If direct pressure were used at either end, the total contents of both ends would be required to reach the same results. It is hardly necessary to note that the first position of the valves will cause the bench to stand still, unless there should be a leak, which is of frequent occurrence. The dimensions of the cylinders were varied according to the work. Roughing benches for the heavy pulls incident to the first five or six passes were 8 inches inside, with $3\frac{1}{2}$-inch piston rods, and were of steel forged tubes $1\frac{1}{2}$ inch thick. Light benches for finishing were $5\frac{1}{2}$ inches inside, 2 15-16-inch piston rods and 17 feet in length of clear stroke.

We had one bench which was nicknamed the "Long Tom." On this we could draw to a finish a tube 4 inches outside, $2\frac{1}{2}$ inches inside and 18 feet long. This bench was 10 inches inside diameter, with a 5-inch piston rod. Such trifles as a steel tag $1\frac{1}{2}$ inch square on the end of a tube were right in line for rupture, and when they broke gave off a report like the discharge of a gun.

While the Pan-American delegates were visiting the factory, we amused them by breaking in two 2-inch square steel of low carbon which, having a high extension limit, made a very nice exhibit of candy pulling.

After the finish draw the tubing must be straightened, inspected for defects, the ends sawed off, and then it is ready for

shipment. Such in brief are the mechanical features of the process, but there are others. To make up the usual stock of tubing carried for bicycle purposes requires 61 varieties of tubing, not including D shapes, triangles, ovals and other special shapes.

Also there may be several kinds of steel in process, all of which entails the utmost care in arrangement to prevent errors. All steels look alike under such circumstances, and as there are on the average about 14 reductions to each variety, the net result is that from five to six hundred varieties of tubes may be in the works at the same time. To avoid any ordinary mistakes, I devised a system which gave us at all times complete knowledge and control of every lot of tubes. Each and every lot or truck load of tubes of about half a ton's weight was numbered and had wired to it a large brass tag.

When these lots were first numbered there was made out a corresponding tag of paper, having in addition worked out on its face the consecutive reductions or draws from start to finish. This tag was sent to the tool room, and hung with hundreds of others in several long rows. The moment a load of tubes came into the bench room from the pickling department, or drying ovens, the boy whose duty it was to get the tools simply looked at the number, and then secured from the tool room the next set of tools to be used on that lot, and that draw was checked off from the paper tag to show that it had been given out.

Each and every person handling tubes was provided with time cards, and put on his card all the numbers passing through his hands during the day. By this system we always knew where the tubes were and had the name of every one who had in any way helped to finish or carry forward the work. We also knew the exact amount of reductions on every piece or lot of tubes throughout the entire process. To produce good tubes homogeneous in texture, high in tensile strength and free from defect requires the utmost care. You are always working between good and evil, as when you give the tubes a good reduction pull you improve or at least keep the original conditions; but when you sink them or simply reduce their diameter you lower the conditions of excellence. If you were to take a $1\frac{1}{2}$-inch tube, 24 gauge, and give it a succession of sinks, no matter how carefully you annealed it, you would have only ribbons by the time you reached half-inch in diameter.

The usual test consists in bending a piece of 1-inch No. 20 tube, annealed, by placing it between two supports or fulcrums 12 inches apart, placing the weight or pressure midway, or 6

inches from each support. Under such circumstances, such a piece of 1-inch tubing will sustain a weight of more than 800 pounds, sometimes as high as 910 being registered. The tensile strength is usually about 67,000 pounds.

At this point I wish to note a curious fact, which I noted years ago at the works of the Washburn Moen Co. in Worcester, Mass. It is a popular notion, and I believe is incorporated in most of the text-books on the subject, that steel wire increases greatly in strength when subjected to several reductions by cold drawing. I wish to state that such is not the case. Take two samples from the same bar and cold-draw one as much as you please. If you anneal the undrawn one as many times as the other, and conduct the tests in an annealed state, not 5 per cent. difference will be observed. But of course, if you test the wire that is drawn with the temper in it as it comes through the die, it will be much higher in tensile strength, but lower in extension. Exactly the same thing occurs in the making of tubing. The metal is refined, but when annealed is but little stronger than before drawing. Tool steel also improves every time it is properly annealed, and many a fine piece of tool work is cracked and spoiled because the steel was not annealed as thoroughly as it should have been.

But I am afraid I am digressing from my subject. It might be well to add a few things before closing on other kinds of seamless tubing besides steel. The squirting or ejecting of lead pipe is, I believe, too common to need any explanation. Seamless copper tubing is made by casting a hollow or ring cake and then drawing the tube much the same as you would steel. As copper can be worked hot, the work can be handled very rapidly, the last reduction being of course cold on ordinary benches in the usual manner. Brass tube, however, needs some special consideration.

There are three ways to produce seamless brass tubes. One is to cast a hollow tube and reduce by successive cold draws in powerful hydraulic benches. As all brass must be scraped to produce a clean surface, the brass ingots are both borea out and turned off after the first pass or reduction.

In France I saw tubes produced by piercing a solid block of brass exactly as tubes are produced from steel in Sweden. The Mannesmann process will also work both on brass and copper.

The Randolph & Clows Co. make tubes by shell reduction, similar to the method employed by the Pope Manufacturing Co. in making nickel steel tubing. For brass the lubrication is with weak soft soap.

I would have gone into details somewhat more extensively had time permitted. My explanations have, I hope, been sufficiently clear to enable you to form a fair idea of not only "how they do get the hole through the steel," but also how both the hole and outside are afterwards finished.

CHEMICAL TESTS OF CEMENT.

By John F. Winford, Chemist of St. Louis Water Department, and S. Bent Russell, Member of the St. Louis Engineers' Club.

[Read by abstract May 3, 1899.*]

In this paper will be given the method of testing cement used in the St. Louis Water Department chemical laboratory.

All Portland cement used in the water department work is analyzed for sulphuric acid, magnesia and sulphur in sulphides. Each of these constituents is held by some authorities to be deleterious if present in excess of a certain proportion. The importance or necessity of such tests will not be discussed herein. There is, however, in the latest specifications used by the St. Louis Water Department the following clause:

"If a sample of the cement shows by chemical analysis more than 2 per cent. of magnesia (MgO), or more than 2 per cent. of anhydrous sulphuric acid (SO_3), or more than one-fourth of 1 per cent. of sulphur as sulphides, the shipment will be rejected."

In inspecting cement for the department a great many determinations of these elements in cement have been made, and especially of magnesia and sulphuric acid. The experience gained in this way has shown that certain precautions are necessary in making the analyses in order to get accurate results. When the rejection of a large shipment of cement and, to a certain extent, the local reputation of a manufacturer's brand depend upon the analysis, one cannot afford to have doubtful results.

No claim is made for originality in the methods used. It is believed, however that there is no published scheme for such tests which covers all the points that come up in making tests of this kind with Portland cement.

Below will be found a detailed account of the operations made for such determinations. No attempt is made to show the reasons for the different operations, and so it may seem to the reader that unnecessary attention is given to some of the details. The beginner is therefore warned to be cautious in departing from the path laid out.

DETERMINATION OF ANHYDROUS SULPHURIC ACID (SO_3) COMBINED AS SULPHATE IN CEMENT.

Place the sample on a flexible cloth or paper; crush any lumps with a spatula; mix thoroughly by rolling, and spread out uniformly. Scoop up portions of the cement from points distributed

*Manuscript received May 23, 1899.—Secretary, Ass'n of Eng. Socs.

over the whole sample; place in a Wedgewood mortar and powder. The portion scooped up should weigh about 150 grams. After powdering place on a glazed paper, mix by rolling and spread. Weigh out 10 grams by dipping up portions from different parts of the sample. Place the 10 grams in a porcelain dish 5 inches in diameter and run 100 c. c. of distilled water into the dish. Stir up the cement and water and add 50 c. c. of strong hydrochloric acid. Lay a glass triangle on the dish, and on the triangle a convex cover glass 6 inches in diameter; place on an asbestos board over a Bunsen burner and evaporate to dryness, or until there is no longer any odor of hydrochloric acid. Remove the burner; allow to cool. Remove the glass triangle and place the cover glass directly on the dish. Run in 50 c. c. of concentrated hydrochloric acid, replace the Bunsen burner and heat to boiling. Add 100 c. c. of distilled water and allow to boil five minutes. Rinse the cover glass with a jet of distilled water into the dish. Filter while hot, using a filter pump and a No. 0 Munktell's Swedish filter, 15 cm. in diameter. Wash the insoluble residue from the dish to the filter by means of a jet of hot water. Wash the insoluble residue on the filter three times with hot water. Pour the filtrate and washings into a No. 5 Griffin beaker, cover with a convex glass, bring to a boil on a wire gauze over a Bunsen burner, add 20 c. c. of 10 per cent. solution of barium chloride, remove the Bunsen burner and allow the precipitate of barium sulphate to subside. Filter on a No. 0 Munktell's filter 9 cm. in diameter, using the filter pump. By means of jet of hot water wash the precipitate from the beaker to the filter, and wash the precipitate on the filter with hot water three times. When the washings have run through the filter, and before the filter is dry, place the filter with the precipitate in a weighed platinum crucible. Cover the crucible and place on a triangle over a Bunsen burner; heat at a low temperature until all the moisture is driven off. Remove the lid from the crucible; place the crucible in an inclined position on the triangle, and arrange the cover so that it projects partly into the crucible and rests on the rim of the crucible and the triangle. Heat to redness until the filter is completely burned. Remove burner, allow to cool and weigh crucible with the ignited precipitate. The difference between this weight and the weight of the crucible gives the weight of barium sulphate, which, multiplied by 0.3433, gives the weight of anhydrous sulphuric acid in 10 grams of the cement. The weight of the anhydrous sulphuric acid multiplied by 100 and divided by 10 gives the percentage of anhydrous sulphuric acid (SO_3) in the cement.

DETERMINATION OF SULPHUR (S) COMBINED AS SULPHIDE IN CEMENT.

Of the sample of 150 grams, prepared as described under "The Determination of Sulphuric Acid," weigh out 5 grams and place in a flat-bottom flask of about 300 c. c. capacity. Insert a doubly perforated rubber stopper into the mouth of the flask. Through one of the perforations extend nearly to the bottom of the flask a globe-shaped funnel tube having a Geissler stopcock and ground glass stopper. Through the other perforation pass a glass tube bent at right angles and extending just through the stopper. To the outside of this tube connect, by means of a piece of pure gum tubing, a Will & Varrentrap's three-bulb nitrogen apparatus containing 1 c. c. of liquid bromine and 25 c. c. of strong hydrochloric acid. Allow 100 c. c. of distilled water to run into the flask through the funnel tube while gently shaking the flask. Close the stopcock of the funnel tube and put 50 c. c. of strong hydrochloric acid in the globe. Allow the acid to pass into the flask gradually by opening the stopcock. When it has all entered flask close the stopcock and insert the glass stopper in the mouth of the globe. Heat the flask now gradually to boiling, and boil until the acid in the nitrogen bulbs gets warm. Detach the bulbs from the apparatus; run the contents into a No. 3 Griffin beaker and wash out the bulbs into the beaker three times with distilled water. Cover the beaker with a convex glass and set to boil over a Bunsen burner. Continue the boiling until all the bromine is driven off. If the liquid is not perfectly clear filter through a No. 0 Munktell's filter paper 9 c. c. in diameter into another beaker of the same capacity. Wash the filter twice with distilled water; set the clear liquid to boil again, having covered the beaker with a convex glass, and add 10 c. c. of 10 per cent. solution of barium chloride. Remove the burner and allow the precipitate of barium sulphate to subside. Proceed now with the precipitate exactly as described under the "Estimation of Anhydrous Sulphuric Acid" until the weight of barium sulphate is obtained. When this weight is obtained multiply by 0.1374, which gives the weight of sulphur as sulphide in 5 grams of cement. Multiply the weight of sulphur as sulphide by 100 and divide by 5 and the result will be the percentage of sulphur as sulphide in the cement.

DETERMINATION OF MAGNESIA (MgO) IN CEMENT.

Of the 150 gram sample, obtained as described under the "Determination of Anhydrous Sulphuric Acid," take 10 grams from different parts of the sample, place in an agate mortar and grind

exceedingly fine. Place on a glazed paper, mix and spread out evenly on the paper. Weigh out very accurately 1 gram of this fine powder taken from points distributed over the sample; place in a porcelain dish $4\frac{1}{2}$ inches in diameter, add 50 c. c. of distilled water and stir up the cement; add 25 c. c. of strong hydrochloric acid while stirring. Lay a glass triangle on the dish and a convex cover glass 5 inches in diameter on the triangle. Place the whole on an asbestos board over a Bunsen burner, evaporate to dryness or until no further odor of hydrochloric acid is given off. Remove the burner, allow to cool; remove the glass triangle and place the convex glass directly over the dish. Add 25 c. c. of strong hydrochloric acid and heat to boiling; run in 50 c. c. of water and allow to boil for five minutes. By means of a jet of distilled water rinse off the cover glass into the dish. Filter immediately on No. 0 Munktell's filter paper 9 cm. in diameter, using the filter pump. Wash out the dish by means of a jet of hot water, and allow the washing to run through the filter. Wash the filter and precipitate three times with boiling hot water. Pour the filtrate into a No. 4 Griffin beaker, cover with a convex glass, add ammonia in slight excess and boil until only a slight smell of ammonia comes from the liquid. Filter immediately, following exactly the instructions given in the preceding operation of filtering. Remove this filtrate to a No. 5 Griffin beaker, cover with a convex glass and heat until boiling briskly on a wire gauze over a Bunsen burner. Run into the boiling solution by means of a pipette 50 c. c. of ammonium oxalate solution containing 1 gram of the salt to 24 grams of water. Allow to boil five minutes; remove the burner and allow the precipitate to subside slightly, but before the liquid cools much filter through a double filter (Munktell's No. 0, 12.5 cm. in diameter). By means of a jet of boiling hot water wash out the beaker, holding in such position that the washings run on the filter, and continue until the filter is full nearly to the top. After allowing the washings to run through the filter, repeat the operation twice. Pour the filtrate into a No. 6 Griffin beaker, and if it is not over 250 c. c. in volume allow to cool; if it is over 250 c. c., evaporate to this volume or to 200 c. c. in a platinum dish and replace into the beaker. This filtrate should be absolutely clear, and if not should be refiltered until it is clear. When the clear filtrate is cold 100 c. c. of strong ammonium hydrate are added and 25 c. c. of a 10 per cent. solution disodium hydrogen phosphate. The liquid is then stirred briskly with a glass rod capped with a piece of pure gum tubing at its lower end. The beaker is then covered with a convex glass and allowed to remain at rest in a cool place for twelve hours.

Filter on a No. 0 Munktell's filter 9 cm. in diameter, using the filter pump. Wash out the beaker with a cold solution made up of 100 parts of strong ammonium hydrate, 20 parts ammonium nitrate and 300 parts of distilled water, allowing the washings to run through the filter. Then by means of a jet sprinkle the side of the beaker with this same solution and rub with the gum cap on the end of the glass rod. Wash the beaker again to the filter. Wash the precipitate on the filter four times with the solution of ammonium hydrate and nitrate. Allow the washings to filter through, remove the filter and precipitate to a weighed platinum crucible; cover the crucible, place on a triangle over a Bunsen burner and heat gently, not above a dull red, until the filter is completely charred. Remove the cover, incline the crucible, lay the cover so that part of it extends into the crucible and rests on the rim of the crucible and the triangle. Heat to a redness until the filter paper is burned to an ash. Remove the Bunsen burner and replace with a Bunsen blast lamp. Heat to a white heat until the precipitate is perfectly white. Set the crucible upright, put on the cover and continue the white heat for ten minutes. Remove the blast lamp, allow to cool and weigh. The difference between this weight and the weight of the crucible is the weight of magnesium pyrophosphate, which, multiplied by 0.3604, gives the weight of magnesia in 1 gram of cement. The weight of the magnesia multiplied by 100 gives the percentage of magnesia (MgO) in the cement.

THE FUNCTION OF A RAILROAD TESTING LABORATORY.

By Samuel Stockton Voorhees, of the Pennsylvania Railroad Co., Altoona, Pa.

[Read at the regular monthly meeting of the Engineers' Society of Western New York, Buffalo, N. Y., May 6, 1895.]

A series of articles* on this subject appeared in one of the railroad journals which covers the ground so fully that a condensed paper may seem superfluous; but this abstract may prove of interest to those who have not the time to read the continued series.

To the casual observer the connection between the running of trains and chemistry may seem obscure, but a little thought will show their intimate relation.

The breaking of a rail, a tire or an axle may mean the loss of many thousands of dollars; an improper lubricant or bearing metal may mean a serious delay; an impure or corrosive water in the locomotive boiler might cause an explosion, and it certainly would result in an increased fuel consumption and cost of shop repairs; the failure of a signal lamp leads to a serious possibility, one that few railroad men care to contemplate; while an inferior or ill-adapted paint would be a constant annoyance and eyesore.

These examples cited are a few of the problems presented to the testing laboratory for solution, and it is possible to guard against such accidents, and in a measure eliminate the cause.

In a broad way, it is the province of the chemist to assist the purchasing agent in selecting such material for the company as will give the maximum efficiency of service at the minimum cost.

With this end in view, the work in the laboratory may be separated into three broad divisions: First, determining the chemical and physical characteristics of the supplies best adapted to the requirements, and covering these points by specifications; second, the routine work of examining shipments bought on these specifications, to determine whether they conform to the requirements; third, experimental work and investigations.

The specification is a vital point; indeed, it is the backbone of the entire structure, as it is the goal toward which all the investigation and experimental work tends. Consequently, before the results of the investigation can be embodied in the official form,

*"Contributions to Railroad Chemistry," by Dr. C. B. Dudley and F. N. Pease, appearing in the *Railroad and Engineering Journal*, December, 188[illegible]

much experimental work must be done, and many practical tests made.

As an example, take the single instance of steel used for fire-box and boiler plate. Samples are sent to the laboratory from locomotives as they come into the shop for repairs, with as complete a history as possible in each case; length of time in service, mileage, character of water used and present general condition of the steel; or, in brief, if the service has been satisfactory, and how the result has been affected by peculiar conditions.

Then from chemical analysis and physical tests of each sample attempts are made to deduce what are the chemical and physical attributes which give to each its peculiar character. It is of the utmost importance to draw conclusions from a large number of widely different cases, and eliminate the variables of personal equation and special conditions as much as possible.

When the percentage of carbon, manganese, phosphorus, silicon, sulphur, etc., has been determined, that will give the tensile strength, elongation and general physical properties necessary for the material best adapted to the requirements of service, a tabulated report is sent to the purchasing agent for distribution among the manufacturers for criticism from the producer's standpoint, and from their report the specification may be modified to insure a working shape. The specifications for steel and iron used for other purposes are evolved in a similar manner.

In the case of oils used for burning and lubricating purposes the requirements are somewhat different. For illuminating oils it is of vital importance to reduce the danger from inflammable vapors to a minimum, by means of a safe fire test and the proper construction of lamps, and at the same time to insure a constant flame during our longest nights.

With lubricating oils and greases, the question involved is largely efficient service at minimum cost. In a suitable machine, tests are made to determine the coefficient of friction with different lubricants at varying speeds, temperatures and pressures, and at the same time the wear of both axle and bearing metal per unit of revolution; these tests, together with the practical tests in service, give a means of determining the value of a lubricant. The petroleum industry is producing such an endless variety of oils, with such different properties, that the field for the expensive fat oil is growing more and more limited, and the chemist is constantly attempting to substitute mineral oils for the latter with safety and economy.

It is hardly appreciated that the cost of paint on a large rail-

road amounts to hundreds of thousands of dollars each year, and a decrease of a fraction of a cent per pound means a considerable saving to the company.

If this can be accomplished with an increased durability of the paint, and consequently a longer life to the structure protected, the economy is large. At the same time, a standard shade and uniform color of the paint will undoubtedly improve the general appearance of the rolling stock.

While speaking of paints, it will not be out of place to mention the influence of detergents on painted or varnished surfaces; nearly all the soaps on the market contain, besides the alkali combined with the fat,—viz, the soap,—varying amounts of free alkali in the form of caustic soda and carbonate of soda, and those two act very energetically on the oils and gums in the paint or varnish.

Indeed, if the percentage of the free alkali is considerable, it often will be necessary to send the car to the paint shop after a single washing.

Enforcing the requirements for a neutral soap will reduce this trouble to a minimum.

At the same time, an analysis of the soap will enable the company to pay actually for the amount it buys.

When the soap is first made it contains considerable water, and is technically termed "green," and a pound bar of such soap will actually contain far less than a pound of dehydrated soap.

If a bar is taken from a shipment at random, weighed and the percentage of alkali, or soap, determined, it is simple to calculate the amount of soap in the shipment, and pay for that amount.

The examination of waters on the companies' lines demands considerable attention from the chemist.

An analysis will usually determine its fitness for boiler purposes, or as a potable water, and the evil, if found, can be either eliminated entirely by using another source of supply or corrected by neutralizing the corrosive action, or destroying the pathogenic germs.

It is scarcely necessary to enumerate more instances in the long list of supplies needed on a railroad. From the few examples cited it can be seen how the same system may be extended to embrace other cases.

In the sharp competition and low prices of to-day there is a constant tendency on the part of the manufacturer to work to the lower limits of the specifications and even fall below the requirements, so it is quite necessary to examine the shipments day by

day, and it is surprising to see how soon the manufacturer notes this fact and acts accordingly.

The experimental work and investigation includes the examination of many worthless nostrums, and also some valuable products where often a chemical analysis will determine the merits of the case without the expensive trial of a service test. Then, too, a substance is submitted for trial which no doubt justifies the claims made, but the cost of the ingredients and of manufacture are out of all proportion to the price charged, or an old rogue is disguised with a new name and complexion, and cast loose upon an unsuspecting public; in either case an examination will detect the fraud.

Besides this work of a purely chemical or physical character, there are certain classes of supplies, as disinfectant, polishing paste, rouge, lacquer, battery solution, zapon, etc., that can be made more economically and better adapted to the requirements in the laboratory than they can be purchased.

Indeed, the scope of a laboratory is so varied and extended, and so much of a field remains unexplored, that one can well quote from Professor Greville Williams, when one thinks of the advance which has been made, and the possibilities in the future. "The impossible is a horizon which recedes as we advance; the *terra incognita* of to-day is boldly marked on the chart of to-morrow."

DISCUSSION.

T. Guilford Smith.—From a manufacturer's standpoint, I question the advisability of drawing up specifications too fully and would cite the case of steel rails. In one case the railroad's specifications even stated the method of making them.

The Erie Railroad has had such a laboratory here.

The Pennsylvania Railroad makes exhaustive tests of everything purchased, and it is the means of saving them large sums of money, as was the case when they changed the color of their cars. Their specifications are very strict, but are not unreasonable.

C. E. Mann.—I should think such a laboratory would be a good thing for the smaller roads centering here.

Association of Engineering Societies.

Vol. XXII. **JANUARY, 1899.** No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

Memorial Meeting in Honor of Col. Henry Flad, September 21, 1898.

When the meeting was called to order, the President, Mr. Wm. H. Bryan, addressed the Club as follows:

The engineer who confines himself to the legitimate practice of his profession rarely accumulates wealth; very few monuments are erected to his memory; it is not often that he becomes famous. What then is his reward? To what may you and I and every engineer look forward?

But, after all, the engineer's rewards are not as intangible as might at first sight appear. His riches lie in the consciousness of duties well performed, of obstacles and difficulties met and overcome, and of the forces of nature conserved to the greatest benefit of mankind. His monument is not the granite column, but the steel arch, the ponderous engine. His fame comes in the esteem of his brother engineers, and of the discerning few who know what engineering triumphs mean.

The Engineers' Club of St. Louis does itself honor in setting aside an evening to the memory of Henry Flad, its first President, and for twelve years the occupant of the chair. He may truly be termed the father of the Club, and we, his children, do well to honor him. Held in the highest esteem, both at home and abroad, occupying the topmost standing in his profession, he rounded out a career which may at once be the admiration and envy of every engineer. Progressive, yet conservative in his work, and with always a smile and a word of encouragement for the young engineer, one had but to know him to esteem and revere him.

But what Henry Flad did for this Club, and what he did for the busy world in which he moved—how, and when, and where he did it—can better be told you by those whose fortune it was to know him more intimately than I did. I therefore ask Mr. Robert Moore to address you.

Mr. Moore.—When a man of the exceptional ability and high character of Henry Flad passes away, his friends and associates may well pause long enough to gather up their memories of the man and of his works, and to put on record their tribute to his worth, for nothing can be more instruc-

tive or inspiring than the life of such a man, and no act more worthy of themselves than to pay their debt of recognition to his noble qualities. And for one who, like myself, has by years of association come to know his great ability and to revere the single-minded unselfishness and fidelity of the man, no task can be more welcome than the opportunity to add my word to your tribute to his memory.

Henry Flad was one of many men of rare ability for whose presence in America we are indebted to the Republican Revolution of 1848-49 in Germany. He was born July 30, 1824, in the Grand Duchy of Baden, near the university town of Heidelberg. His father, Jacob Flad, dying within the same year, his mother, Francisca Brunn Flad, very soon afterwards removed to the town of Speyer, a few miles distant upon the left bank of the Rhine in the Rhine Palatinate, a province belonging to Bavaria. After passing through the preparatory schools of Speyer, young Henry entered the University of Munich, in Bavaria, where he took the polytechnic course.

After his graduation, in 1846, at twenty-two years of age, he was given a position in the engineering service of the Bavarian Government, his first employment being on works for the improvement of the River Rhine. The years which immediately followed, particularly the years 1848 and 1849, were years of great political commotion throughout Europe. Encouraged by the success of the revolution in France which drove out King Louis Philippe, the longings of the German people for a freer and more united government found such vigorous expression that the princes of the many petty states into which Germany was divided acceded to the convocation of a National Assembly or Parliament which, in May, 1848, met in Frankfurt to frame a constitution for United Germany. Unfortunately the deliberations of this assembly showed such wide differences of opinion and so little ability to unite in any workable plan that the ardor of the more conservative classes began to cool. The princes seized their opportunity to reassert themselves and repudiated the authority of the Parliament.

In Southern Germany the champions of the Parliament took up arms in its behalf. Amongst them was Henry Flad, then in his twenty-fifth year, who joined the Parliamentary army as a captain of engineers. Fortune, however, was against them, and after several engagements the Parliamentary army was driven into Switzerland and disbanded. Meantime its leaders were placed under the ban, and Captain Flad, with many others, was sentenced to death.

Under these circumstances he very naturally turned his face westward and took passage for the United States, where the right of the people to govern themselves has found its fullest expression. He landed in New York in the autumn of 1849.

His first employment after his landing was as a draftsman in an architect's office. It was not long, however, before he entered the engineering service of the New York and Erie Railroad, then under construction, his headquarters being at Dunkirk, at the extreme western end of the road. Mr. James P. Kirkwood and Mr. James H. Morley, with whom Captain Flad was afterwards associated, were also employed at this time on the same road. After the completion of the New York and Erie Railroad, in 1851, we hear of Captain Flad first as located for a time at Tonawanda, between Niagara Falls and Buffalo, and then, in 1852, as an assistant engineer in the

construction of the Ohio and Mississippi Railroad from Cincinnati to St. Louis, his headquarters being at Vincennes, Ind.

Upon the opening of the Ohio and Mississippi Railroad to St. Louis, in 1854,—this being the first railway to reach St. Louis from the East,—Captain Flad went to Missouri as an assistant engineer on the Iron Mountain Railroad, of which his former colleague on the Erie Railroad, Mr. James H. Morley, was the chief engineer. During the construction of this road Captain Flad was located at Potosi, Missouri. After its completion to Pilot Knob, where for a number of years it ended, he became land and tie agent of the railroad company, with headquarters at Arcadia, Missouri. During this period, viz., on September 12, 1856, Captain Flad was married to Miss Reichard, of St. Louis.

Upon the outbreak of the Civil War, in 1861, Captain Flad came to St. Louis and enlisted, June 15, as a private soldier in Company F, of the Third Regiment, United States Reserve Corps. From this rank he rose rapidly, advanced to be corporal and then sergeant.

In July, 1861, a regiment known as the Engineer Regiment of the West, recruited mainly in the States of Illinois and Missouri, was organized by Col. J. W. Bissell, and Henry Flad was made captain of Company B. In August of the same year he was detailed by General Fremont, then in command at St. Louis, for service in the construction of fortifications at Cape Girardeau, Mo., where he remained for several months. Later in the year, when Fremont was succeeded by General Halleck, Captain Flad was ordered to join General Pope in southeast Missouri, and served as a staff officer through the campaign of New Madrid and Point Pleasant and the taking of Island Number Ten, after which he rejoined his regiment at New Madrid. He was with his regiment at Fort Pillow and Pittsburg Landing, and in the operations before Corinth. During the summer of 1862 he was engaged in repairing the Mobile and Ohio Railroad, in building forts at Corinth, and in repairing the Mississippi Central Railroad. He was also engaged in Grant's advance on Grenada. In February, 1863, he was ordered to Young's Point, where he was employed in engineering work, as he was later at Baxter Bayou, Lake Providence and Bayou Macon.

In April, 1863, he had charge of the repairs of the Memphis and Charleston Railroad at Memphis, Grand Junction, Jackson and Columbus. In October of the same year he was employed in repairing the same railroad east of Corinth, under General Sherman, and was with him at Cherokee, Bear Creek and Iuka in northern Mississippi.

Meantime he had been promoted, November 17, 1862, to the rank of Major, July 30, 1863, to that of Lieutenant-Colonel, and October 16, 1863, to that of Colonel. On January 1, 1864, at Nashville, Tenn., he was transferred, as Colonel, to the First Regiment of Engineers, Missouri Volunteers, a new regiment formed by the consolidation of the former engineer regiment and the Twenty-fifth Missouri Infantry. During the summer of 1864 he was engaged in completing the Nashville and Northwestern Railroad from Nashville to Johnsonville, and in constructing defensive works. In August he was ordered to Atlanta and served here and in this neighborhood until about the first of November, his last work being the construction of a new line of fortifications at Atlanta.

At this time the term of enlistment of seven companies expired. The command of the remaining five companies then, under the army regulations, devolved upon the Lieutenant-Colonel, and the Colonel was mustered out

November 12, 1864, at Nashville, Tenn. His term of service had been three years and six months, during which time, with not more than a week's leave of absence, he had been constantly in the field. Through it all he was never sick, wounded or captured.

Upon being mustered out, Colonel Flad returned to St. Louis, and began to look around for employment in his profession. In a short time the agitation for an improved water supply for St. Louis took form in a State law authorizing the appointment of a Board of Water Commissioners, charged with the duty of making surveys and plans and constructing a new system of waterworks for the city. Soon after the organization of the new board, in the spring of 1865, Mr. James P. Kirkwood, who had formerly been chief engineer of the Pacific (now the Missouri Pacific) Railroad, and had just completed the building of new waterworks for Brooklyn, N. Y., was appointed chief engineer, and Henry Flad, chief assistant engineer.

Surveys and investigations were at once begun, and. by the end of the year, a plan was presented for new works with intake, settling basins and filter beds at the Chain of Rocks, and a distributing reservoir on what was then known as Rinkels Hill, on Easton avenue, near the present city limits. This plan received the approval of the Board of Water Commissioners, and, as subsequent experience has abundantly proven, was undoubtedly the best. But, besides running counter to some private interests, it involved such a large outlay and such a radical departure from the old plan that on the part of many leading citizens as well as the city authorities it encountered an overwhelming disapproval. The opposition finally became so great that the Water Commissioners were called upon by the City Council to resign. To this demand they presentlv acceded, and, in July, 1866, a new board, committed to a new plan, was appointed. Meantime Mr. Kirkwood had been commissioned to go to Europe to study the subject of filtration, and Colonel Flad was left as acting chief engineer. In December, 1866, a revised plan, with intake and settling basins at Bissel's Point and a distributing reservoir on Compton Hill, substantially as afterwards built, was presented.

Early in the following year the act organizing the Board of Water Commissioners was amended, the number of members being reduced from four to three, and in March, 1867, a new board was appointed with Colonel Flad as one of its members. This position by reappointment he held continuously for eight years, or until April, 1875. During this time, and under his general supervision, the new waterworks were completed and put into service during the year 1872.

Whilst he was still acting as assistant engineer to Mr. Kirkwood, Colonel Flad made the acquaintance of Captain James B. Eads, who was at that time employed upon plans for gun carriages and turrets. The rooms occupied by the Water Board being larger than they then needed, Captain Eads, upon his request, had been granted space in which to set a draftsman at work. This was followed by frequent discussions between the two men upon engineering questions, and this led to a mutual recognition of each other's abilities and laid the foundation of a life-long friendship. When, therefore, in 1868, Captain Eads was ready, as chief promoter as well as chief engineer, to begin the work of constructing the great bridge over the Mississippi River at St. Louis he very naturally tendered the position of chief assistant engineer to Colonel Flad. As the duties of the latter,

as member of the Board of Water Commissioners, did not require all his time, this opportunity to take part in this most interesting and important work was gladly accepted, and he retained his connection with it until its completion in 1874. Some of the boldest features of this great enterprise, such as the method of erection without false work, were due to Colonel Flad.

During 1875 and 1876 he was engaged as consulting engineer in various works in conjunction with Mr. Charles Pfeiffer, who had been associated with him on the St. Louis bridge; Mr. Thos. J. Whitman, chief engineer of the Waterworks, and Prof. Chas. A. Smith, of Washington University. Amongst other engagements he was engineer for the commissioners who purchased and laid out Forest Park.

In the autumn of 1876 the new charter of the city of St. Louis, by virtue of which the city was separated from the county of St. Louis and made, as to its local affairs, to a large degree independent of the State Legislature, was inaugurated, and Colonel Flad was elected the first President of the newly constituted Board of Public Improvements. This office he held continuously for nearly fourteen years, being re-elected in 1880, 1884 and 1888.

The problem to which the new board addressed itself was that of taking the whole system of municipal public works out of the mire of politics and placing them upon the basis of merit and fitness. Into this work Colonel Flad entered with characteristic zeal and a determination which nothing could shake. His efforts were crowned with entire success, so that during the whole period of his administration the board over which he presided had the entire confidence of the whole community. Every citizen felt sure that in every department of the public works the city received a dollar's worth for every dollar spent, and in this respect St. Louis became a model for other cities.

In the spring of 1890, having become somewhat weary under the increasing burdens of his position, he resigned his office as President of the Board of Public Improvements to accept membership in the Mississippi River Commission in the place made vacant by the resignation of Captain Eads. In this latter position he remained until his death, giving to the work his best energies and nearly the whole of his time. The new policy of deepening the low water channel of the river by dredging rather than by contraction works, which the commission adopted during his membership, was very largely the result of his efforts.

Colonel Flad was a charter member of the Engineers' Club of St. Louis, and was its President for twelve years, from 1868 to 1880. He became a member of the American Society of Civil Engineers February 15, 1871, and was President of the Society for the year ending January 19, 1887, thus receiving from both organizations the highest honors within their power to bestow.

His death occurred June 20, 1898, at Pittsburg, Pa., where he stopped on his way home from a meeting of the Mississippi River Commission to visit Mr. Godfrey Stengel, a life-long friend who had come with him on the same ship to America forty-nine years before. He died very suddenly of acute heart failure whilst walking home from one of the parks in company with Mr. and Mrs. Stengel. Up to the last moment he was in excellent spirits and died without pain as without fear.

As an engineer Colonel Flad was remarkable for his great fertility of

invention. For every new problem he had not only one but many solutions, and the rapidity with which he grasped all its conditions and framed his plans to meet them amounted to genius. In doing this he was not limited by precedent, but looked instinctively for new and better methods than any before known. In boldness and originality he has had but few equals in the annals of the profession. And, like the most successful workers in every field, he delighted in his work for its own sake. Nothing could exceed the interest with which he attacked a new problem, and he gave himself no rest until he had solved it. The solution once found, however, the whole subject ceased to interest him, and he passed on to something new. This trait is illustrated by the fact that, although he took out numerous patents for new and useful inventions, to their introduction and utilization he gave no thought. It was the work, rather than its rewards, for which he cared.

As a man, he was equally great. His unassuming modesty, his perfect candor and simplicity, his unflinching courage, his absolute fidelity to his convictions, his single-minded subordination of personal to the public welfare,—qualities which were written in every line of his face and manifested in every act of his life,—all stamped him as a man of the highest type. No one who knew him but believed in him without limit. His name was a synonym for fidelity and skill, and all knew that every work committed to his charge would be well done and come from his hand as sound and flawless as the man himself.

This evident and perfect integrity of purpose made his public service a legacy of incalculable value to his fellow-citizens. His life was a demonstration of how honorable the public service could be made, and is an encouragement to those who have not yet lost faith in the possibility of having this service in all its branches lifted to the same standard to "abate no jot of heart or hope," but still work on for the accomplishment of this high end.

To us, his fellows in his chosen calling, his name and example are specially precious. For in him was realized the highest ideal of the engineer,—a man of trained intellect, controlled by an iron will, and directed to the noblest public ends. And the fact of his success in attaining this ideal will inspire others to frame their lives upon the same noble lines.

Dr. Woodward.—Mr. President and Gentlemen, I had supposed that Mr. Pitzman would follow Mr. Moore, but I am very glad to say a word at this point, or at any point, when the name of Henry Flad is before us. I felt, as I looked out into the storm to-night, that on any other occasion I could easily have stayed at home, but under no consideration would I be willing to be away when I was invited to come to a memorial meeting in honor of Henry Flad.

I have known Henry Flad a long while; and I have in part, I think, appreciated his high character and his great skill. I appreciate the exact justice with which Mr. Moore has treated him, how he has seen clearly into his intellectual, moral and social nature, and I indorse it all, every bit of it.

I came to this city in 1865, just when Colonel Flad was freed from his military duties and had begun work really in the city of St. Louis. The story that has been told you shows that from 1865 to 1898, almost continually from 1865 until 1880, Colonel Flad gave his undivided attention to the interests of this city, including, of course, the construction of the bridge.

Then I was quite a young man, in 1865,—I did not consider myself an

engineer at all; I was hardly, in fact, in touch with the engineering profession; but I had not been in St. Louis long before I began to feel the attraction of that society which clustered around the first Board of Water Commissioners, one of whom was Colonel Flad, another Mr. Whitman. There were Mr. Davis and a few others, among them Colonel Mysenberg, who always sat around the table in the old Water Commissioners' Office. And all of us felt Colonel Flad was the main man; as Mr. Moore has said, he was the father, and the others, as it were, his children. Mr. Kirkwood was not there; I did not have the honor or pleasure of his acquaintance.

But from that time to the day of his death Colonel Flad was my friend, and I drew inspiration from his lips and from his example. The problems of the bridge, the problems of the waterworks, were of unfailing interest in those days, and it was there that I became personally interested in the bridge and in all that related to it.

There was one thing about Colonel Flad that inspired the admiration of all, and that was his absolute intellectual and moral honesty. He was honest toward everybody and thoroughly honest with himself. It was impossible for him to deceive anyone, and it was equally impossible for him to deceive himself. That is a characteristic which is not fully appreciated, but I think that he possessed it, and he stood as a tower of strength and a splendid example to the young engineers who are growing up in this city. It has been my fortune to have something to do with the training of a large number of engineers, and I think that no one man's life has had more to do with their general high character than the constant example of Henry Flad.

His friendships were largely inspired by intellectual and professional sympathy. It was impossible for him to be associated with a good engineer without being that engineer's friend, his warm friend.

Mr. Moore has told you about Colonel Flad as a soldier. I can think of him only as an engineer and as a man. As a soldier he must have been good as he was as an engineer.

I remember one trying month, or rather a part of a month, when they were sinking the first caisson under the east pier of the St. Louis Bridge. I was deeply interested in watching the bridge from the beginning to the end of its construction; Colonel Flad, Mr. Pfeifer and Colonel Roberts divided the twenty-four hours of the day between them, each serving eight hours, taking charge of the work of sinking the first caisson until it rested firmly and safely upon the sand. During that portion of the work, during the storm and rush of water, everything was of the deepest interest. Of those men each kept a log which recorded everything that was done and their experience, as a warning to the next man who followed, and no man left the work until his successor was in place to relieve him. I have read that log through a great many times, as I have read everything Colonel Flad left in connection with his work on the bridge; and you can readily understand how, as I followed his personal experiences, I read his thoughts and shared with him the anxiety that he felt, and the anxiety that the other engineers felt while that work was going on.

He was a man of undaunted courage. He had the courage of his convictions, whether the question was one of engineering or one of municipal policy or whatever it was. He was never found wanting.

Mr. Bryan says we do not build high monuments to engineers. But his monument stands. He has a large share in the St. Louis Bridge, how large a share no man can tell. He never was jealous of other engineers,

he never was eager to claim priority of thought or device; and how fully his suggestions entered into that steel arch, and how fully "Henry Flad" was written all over it in imperishable characters, no one can exactly tell. Captain Eads and Mr. Pfeifer and two or three other men were in constant intercourse. They were men who were willing to take and able to give.

I remember a story told during the war of a man who had been employed previous to his enlistment as a maker of locomotives. On one occasion in the early days of the war his regiment was halted in the presence of a disabled engine between Annapolis and Washington. The Colonel marched down the line and said: "Is there any man here who knows how to repair a locomotive, and put it in shape?" One man stepped out and said: "I know something about locomotives." He went into the engine house and found what you would call an old rattletrap of a locomotive, but his name was written all over it. He had had a share in the building of that locomotive and he was very quick to assist in putting it in order again. Now that was, in a certain sense, his monument. Colonel Flad's monument lies all around this city. Every cup of water we drink, every comfort we enjoy, the comfort we take in our well-built streets—so far as they go—and in many other schemes of municipal improvement, we notice the monument of Henry Flad, and I feel it due to him and to this Club, to the engineering profession, that the young men coming after us know that.

I am glad that Henry Flad's picture will always hang in the rooms of the Engineers' Club, glad that the young men studying engineering may realize how grand a profession it can be in the hands of a master like Henry Flad. There is something greater than merely the accumulation of wealth; men may accumulate a glory that hangs around them as it hangs to-night and always will hang around the name of Henry Flad.

Julius Pitzman.—I appreciate the feeling which prompted our colleague, Mr. Moore, to eulogize our departed friend, Henry Flad, because his association with him in the Board of Public Improvements has enabled him to study his character and to measure his ability. I believe that all those of you gentlemen who have known Colonel Flad intimately will agree with me when I say that he was one of the few men of high position who constantly grew in your estimation on close acquaintance.

That love of liberty which filled the hearts of the young students of the German Universities swept over the country and caused the revolution of 1848, brought him, with many other bright and enthusiastic young republicans, to our shores, to enjoy here that freedom for the attainment of which, in Germany, they had risked their lives.

Colonel Flad had great advantages over most of his friends who came with him, for the reason that in the United States engineers of scientific attainment and practical knowledge were few and far between; and, possessing those qualifications, he was enabled to procure positions in which he could display his ability and advance in his profession by the practical application of his theoretical knowledge. My acquaintance with him dates back to about 1856, when he was the engineer in charge of construction of some of the most difficult portions of the Iron Mountain Railroad. During the time he was in the employment of that road he occasionally came to St. Louis, and it was always a great pleasure to his friends to meet him and to learn from him the manner in which he overcame the difficulties he encountered.

Just as soon as war was declared, he, like all those who had fought in

Germany on the revolutionary side, volunteered at once, and responded to the call of the President, entered as a private in the Third Regiment of Missouri Volunteers; was very soon advanced to corporal, then to sergeant, and, when General Fremont came to take charge of the Army of the West, he was appointed Captain of Engineers. Subsequently the Engineer Regiment of the West was organized under command of Colonel Bissell, and, as Mr. Moore has stated, in June, 1862, Henry Flad was elected captain of one of the companies. When this regiment was ordered to the front, it was soon discovered that it, like the majority of volunteer regiments, had elected officers who were not qualified to discharge the duties required of them. Then the weeding-out process commenced. In consequence of this Captain Flad was steadily advanced. He was first placed in command of a battalion, subsequently advanced to the position of lieutenant-colonel, and in October, 1863, he was made colonel of the regiment.

Notwithstanding that his regiment did very little fighting, it rendered the most valuable service. As the Army of the Tennessee, to which his regiment was attached, advanced, nearly all the bridges on the highways as well as on the railroads, were destroyed, and, to prevent a delay in advancing the army, a part of his regiment was kept near the front in charge of the pontoons, to enable us to cross the rivers and sloughs without delay. The large body of the regiment was generally kept in the rear to rebuild railroad bridges and to repair the roadbed so as to keep open the communication with our base of supplies.

You can easily imagine the great value of the service rendered by his regiment, when you take into consideration that General Grant had about 100,000 men in his commands and operating hundreds of miles south of its base. The reports you gentlemen have heard from Santiago, where we had to supply only 25,000 men, ten or fifteen miles from the landing, and where we appeared to have encountered great difficulties in supplying that small force with ammunition and with the necessities of life, must convince you of the difficulties of supplying an army advancing as rapidly as Grant's army did in those campaigns, and you can readily understand the importance of the services rendered by such a regiment.

On several occasions, in my presence, Generals Grant and Sherman spoke in the highest terms of Colonel Flad and of the efficiency of the regiment under his command, and they could always rely upon his reports as to the time when a line of communication could be opened.

Mr. Moore and Dr. Woodward have given you a full statement of the work done by Colonel Flad after his return to St. Louis, when the time for which his regiment enlisted had expired, but I feel it to be my duty to call your special attention to the very important service he has rendered by accepting the Presidency of the Board of Public Improvements. The reputation for ability and unquestionable integrity which the Board of Public Improvements has enjoyed, and does still enjoy, is attributable to him more than to any other individual member of the board, and it was due to his influence that the best results were obtained by perfect harmony between the heads of departments and by close attention to the intelligent discharge of his duties. The reconstruction of the streets in the central part of the city was carried into effect against the combined influence of nearly all the real estate owners, and of the landed aristocracy of St. Louis, and this victory was not due to political influence, but it was achieved by the moral

weight which the Board of Public Improvements exercised, and by the faith the public had in the honesty and integrity of the Board.

Colonel Flad's sudden death has prevented him from completing his plans for the improvement of the Mississippi River, and has deprived us of the most honored and revered member of our profession, and I hope that the shining example he has set may exercise a beneficial influence upon the members of our profession.

We hardly appreciate the difficulties Colonel Flad encountered at the time he was elected to the Presidency of the Board of Public Improvements. St. Louis was at that time in the county of St. Louis and was governed under the provisions of the statutes of the State. The separation under the provisions of the scheme and charter created an independent corporate body of St. Louis, and it required the drafting of appropriate ordinances and the inauguration of an entire new system for the government of the city and the management of its affairs. In this difficult position Colonel Flad proved himself to be the right man in the right place, and he, with the assistance of his associates, has inaugurated a system of government which, for the time being, has proved a great success.

I don't know that the German Government has imposed the death penalty upon any of the revolutionists except upon a few who were captured at the time. In later years general amnesty was granted, but very few who had emigrated to the United States ever returned to avail themselves of it. Carl Shurz, who was one of the revolutionists and who took a very prominent part, visited Germany some fifteen years ago, and he was not shot, but instead was invited to dine with Prince Bismarck, and he was well received by Government officials.

Mr. Moore.—They were not in the jurisdiction.

Mr. Pitzman.—In 1848 the revolutionary element in Berlin had absolute control of the city, and when those that were killed by the soldiers were buried, the King was made to come to the balcony and take off his hat until the entire procession had passed. There was, however, a total lack of organization and the glory lasted only a few weeks. The troops from those portions of the kingdom which were not affected by the revolutionary spirit were brought to Berlin and to the other cities which had revolted, and the despotism was very soon re-established and persecutions commenced.

Prof. J. B. Johnson.—To all who knew him professionally, the life and work of Col. Henry Flad will serve as a perpetual stimulus to noble endeavor. In him were united the three essentials of a great engineer,—native genius, technical training, and moral character. He had the faculty of seeing things in their relations of cause and effect, and could vigorously calculate the proportionate influences of each of many conspiring agencies. In devising means to ends he was marvelously ingenious, and never hesitated to follow his plans in the working out of new problems. He was absolutely honest in thought, word and deed, both to himself and to others. By no possibility could he have led himself, by any kind of specious or sophistical reasoning, to an oblique view of any moral question. The rightness or wrongness of any act was by him so clearly perceived that he could not be led into any kind of compromising situation. Although more severe with himself than in his judgment of others, yet whenever he had lost confidence in the integrity of any man, he had no future use for him and could with difficulty conceal his dislike for him. He was particularly

impatient with what he might consider professional or scientific untruth, whether indulged in ignorantly or knowingly, and his enthusiasm for the scientifically true and for the morally right may sometimes have led him into uncharitable judgment of the acts of other people.

The void left by the death of a great man can never be filled, for he had an individuality all his own which cannot be duplicated. So we feel that in the death of Colonel Flad a vacancy has been created in the ranks of the engineering profession which cannot be supplied. His memory, however, shall ever be treasured by his contemporaries as a high ideal to which they may aspire and by which they may with profit compare themselves; and his shining example of what an engineer may, and should be, will shed its benignant light upon many future generations of engineers.

482D MEETING, JANUARY 4, 1899.—The meeting was held at 1600 Lucas Place, at 8 P.M., with President Colby in the chair. Twenty-four members and four visitors were present. The minutes of the 480th and 481st meetings of the Club and the 266th and 267th meetings of the Executive Committee were read and approved.

The Secretary announced that he had received an application for membership from Mr. Louis Ruckert. The application for membership of Mr. Wm. F. Scott having been favorably reported upon by the Executive Committee, this gentleman was balloted for and elected a member of the Club.

The President stated that as no one had been chosen for the office of Vice-President on the latter ballot, he would declare the office vacant, and call for nominations.

The Chair stated that he would rule that all those who had been nominated for Vice-President at the 480th meeting were still in nomination.

An appeal was taken from this ruling, and, on being put to a vote, was carried.

The following nominations were then made for Vice-President:

E. J. Spencer, E. A. Herman, F. E. Nipher and M. L. Holman. On the first ballot there was no election, as none of the candidates received a majority of the votes cast. On motion, the name of the candidate receiving the lowest number of votes was dropped and a new ballot taken. On this ballot F. E. Nipher was elected.

The Secretary announced that during the year 1898 resignations had been received from the following members: N. W. Eayrs, W. K. Hatt, Wm. H. Boehn, A. B. Man, E. W. Stern and H. M. Chittenden.

The Secretary read a communication from the Association of Engineers of Virginia, announcing that the organization had disbanded.

The paper of the evening, by Mr. S. E. Freeman, was then read. It was entitled "Steel Forgings, Solid and Hollow." The paper described the practice at the Bethlehem Iron Works in making steel forgings, and discussed the advantages of hollow over solid castings. A large number of lantern slides were exhibited, showing the processes of making large steel forgings.

The discussion following this paper was participated in by Mr. Borden and Professor Johnson.

There being no further business, the meeting adjourned.

RICHARD MCCULLOCH, *Secretary pro tem.*

483D MEETING, JANUARY 18, 1899.—The meeting was held at 1600 Lucas Place at 8.15 P.M.; President Colby in the chair. Thirty-one members and ten visitors were present. The minutes of the 482d meeting were read and approved. The minutes of the 268th meeting of the Executive Committee were read. The application of Mr. Louis Ruckert having been approved by the Executive Committee, he was balloted for and declared elected a member of the Club. The application of Mr. H. S. Wilson for membership was announced.

Mr. J. A. Ockerson then read the paper of the evening, entitled "The Southwest Pass of the Mississippi River." The paper described fully the methods of the last survey, and the physical characteristics of the pass, mentioning especially the character of the banks and the peculiar mud lumps which form at various points. The several openings from the pass to the gulf were mentioned and their dimensions given. Methods used in making soundings, both in the pass and in the gulf at its mouth, were fully explained, so the accuracy of the survey was apparent. The slope of the river in the pass was stated and the effect of the winds and tides on the slope discussed. The movement of the crest of the bar at the mouth of the pass was described as shown by the surveys of different periods, and the conditions affecting the rate of advance discussed. The advance is due mainly to the rolling of the sand up the rear and down the front of the bar. The most of the silt brought down by the river is deposited before reaching the bar and goes to building up the banks. Where the river divides into the several passes, the discharges of each pass were measured daily, and the discharges of each given in percentages of the total discharge of the river. The plans of the Board of Engineers appointed to report on the improvement of the S. W. pass were set forth, and the nature of the jetties which they proposed was described; also the necessity for the improvement of this pass was discussed. Drawings and photos were exhibited showing the various points. The discussion following was participated in by Messrs. Flad, Connor, Freeman, Bouton, Colby, Herman, Russell and Turner.

The President called attention of the Club to the forthcoming bulletin and its advantages for advertising.

An Entertainment Committee for 1899, consisting of Messrs. Wall, Zeller and Dunaway, was appointed. On motion of Mr. Bryan, a committee to draft resolutions on the death of Mr. Winthrop Bartlett was appointed. Mr. M. L. Holman was named as chairman and authorized to select his two associates. There being no further business, the meeting adjourned to another room, where lunch was served.

E. R. FISH, *Secretary.*

James Francis.—A Memoir.

BY ARTHUR T. SAFFORD AND WALDO E. BUCK, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, January 25, 1899.]

THE death of James Francis, on December 1, 1898, a little over six years after the death of his father, James B. Francis, removes the second representative of that name which has been so closely identified with the history of Lowell, Massachusetts.

James Francis, or, as he was so generally known, Colonel Francis, was

born in Lowell, Mass., March 30, 1840. His early education was obtained in the public schools of Lowell; later his instruction was private. In his twentieth year he entered the Lowell Machine Shop as an apprentice, studying and working in the different departments until the breaking out of the Civil War, when, at the first call to arms, he enlisted, with a number of the younger men in the Lowell Machine Shop, in Company A, of the Second Massachusetts Regiment. He served throughout the war. A brief account of his services, from an obituary in one of the Lowell newspapers, says: "He was under General Patterson in the Shenandoah Valley, with Banks in his retreat, with the Army of the Potomac in the winter of 1862-3, and participated in the battles of Cedar Mountain, Chancellorsville, Antietam and Gettysburg. He was afterwards in the corps sent to quell the draft riots in New York. He then served in the West and along the line of the Chattanooga Railroad; was with Sherman in his march to the sea, and participated in all the engagements during that march. He was wounded in the battle of Antietam.

"Mr. Francis received the following commissions: Second Lieutenant, May 25, 1861; First Lieutenant, November, 1861; Captain, August 10, 1862; Major, July 4, 1863; Brevet Lieutenant-Colonel, March 13, 1865, for distinguished gallantry in Georgia and the Carolinas. He was commissioned Lieutenant-Colonel July 24, 1865."

After being honorably discharged, in August, 1865, he became associated with the engineering work at Hoosac Tunnel as an assistant. He came back to Lowell in 1866, becoming, in April of the next year, first assistant engineer of the Locks and Canals. On January 1, 1885, he succeeded his father, James B. Francis, as agent and engineer of the Locks and Canals, and remained in charge of the different interests of this company until 1894. From that time until his death he was agent of the same company, having charge of the rents, real estate and system of fire protection.

Although Colonel Francis had been failing rapidly for the two months previous to his last sickness his death was a great shock to all those associated with him. Previous to the last years he seemed to have borne almost a charmed life. Mention has been made of his being wounded at Antietam. It was a flesh wound through the hand; otherwise he came out of the war unscathed.

It is remarkable that he should have braved the dangers of the war to meet with his greatest accidents in the pursuit of his profession. In 1888, during the construction of the wall of the Pawtucket Canal, while standing on the top of the wall, he was struck by a drag box and knocked off into the canal, falling more than twenty-three feet, onto a pile of dirt and broken stone. Both of his legs were broken; each in more than one place, but, after careful treatment, excepting for a slight limp, he was able to walk with comparative ease. His recovery was looked upon as almost miraculous. In the summer preceding his death he was thrown from his carriage to the ground without any chance to break the fall. To a man of his age and weight, the shock was particularly severe and doubtless aggravated the conditions which caused his death. He never fully recovered from this accident, but steadily lost strength until he passed quietly away without suffering of any kind.

His engineering work has always been so intimately associated with carrying out the plans of his father, James B. Francis, that it is difficult to say just how much of originality Colonel Francis exercised in his work.

He certainly was not radical in his methods or ideas; he believed himself warranted in following the path laid out by the elder Francis, so successful had the latter been in the management of the water power and land of the Locks and Canals.

There are two things which are particularly characteristic of Colonel Francis in all his relations to his engineering work and associates and to his fellow-men,—his great-heartedness and his absolute honesty of thought and purpose. His work was done entirely for the sake of its use in the world and not for his own advancement.

One had to be brought into intimate contact with Mr. Francis to know his character. Few, if any, heard from Colonel Francis himself of anything that he did in the war; but the soldiers of his command have told of repeated occasions when Colonel Francis would spend the time, after one of the great battles, searching for the wounded to minister to them; and the lives of several men were saved, through his own personal efforts, to bear witness to his unselfishness. Among the poor and unfortunate Colonel Francis has been generous to a fault, and many a one will miss his ready sympathy and open purse.

His absolute honesty of thought and purpose was shown in his relations to the mill corporations whose agent he was. The rights of each, as laid down in their indentures, were almost religiously observed; and there was no attempt to cater to the great corporations and disregard the rights of the small ones. Absolute impartiality was his watchword.

Probably Colonel Francis's greatest achievement, outside of the good management which characterized his work in Lowell for thirteen years, was the scheme for the regulation of the power on the Concord River at what is known as Whipple's Falls, Lowell. The different interests there had been involved in lawsuits for years; no one corporation was able to get its lawful property, and the problem was given by the court to Colonel Francis to straighten out. He designed a system for the proper regulation of the water power, and this system has been in use since June 19, 1894, to the satisfaction of every interest concerned. This was one of those involved cases which need not so much a bright engineer as a broad-minded man who strives only for justice to all.

There are some men whose lives are remembered by a series of great works accomplished, and their names invariably suggest to the mind the character of their works. This I think can be said of the elder Francis. Then there are a few, who, although working along lines laid down by others, yet add to their work such a trust in the greatness of God and the nobleness of man that they elevate this sphere of usefulness and make it resemble the divine work.

The younger Francis belonged to this latter class, and those who knew him well will remember him well. Any young man who has been brought into close contact with him would hesitate to do anything unworthy of his manhood.

Colonel Francis became a member of the Boston Society of Civil Engineers September 16, 1885, and of the American Society of Civil Enginers January 4, 1893.

He leaves a son, Joseph S. Francis, a graduate of Harvard University and a lieutenant in the First Massachusetts Heavy Artillery. He has followed the profession of his father and grandfather, being now an assistant engineer in the Philadelphia branch of the American Bell Telephone Company.

Boston Society of Civil Engineers.

Boston, Mass., December 21, 1898.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock p.m.; President Howard A. Carson in the chair; fifty-five members and visitors present. The record of the last meeting was read and approved.

Messrs. Charles W. Aiken, Harold K. Barrows, Frank H. Mills and George E. Stratton were elected members of the Society.

The President announced the death of Col. James Francis, a member of the Society, which occurred December 1, 1898. The President was authorized to appoint a committee to prepare a memoir, and since the meeting has named as members of the committee Messrs. Waldo E. Buck and Arthur T. Safford.

The first paper of the evening, entitled "Power and Equipment of Electric Railways," by Messrs. H. H. Hunt and C. K. Stearns, was then read by Mr. Hunt.

Mr. A. D. Adams discussed briefly the means which had been used to prevent electrolysis in Boston and other cities.

The thanks of the Society were voted to Messrs. Hunt and Stearns for their kindness in presenting to the Society so interesting and instructive a paper.

Prof. Jerome Sondericker read the second paper of the evening, entitled "Comparative Tests on Different Forms of Cement Briquettes." A general discussion followed on the testing of cement and forms of briquettes.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., January 25, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President Howard A. Carson in the chair; ninety-three members and visitors present. The record of the last meeting was read and approved.

Messrs. Arthur B. Corthell and James C. S. Taber were elected members of the Society.

On motion of Mr. R. S. Hale, the President was requested to appoint a committee of three to report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed as this committee Messrs. R. S. Hale, F. L. Fuller and H. B. Wood. Later in the evening this committee reported as members of the nominating committee Messrs. W. E. McClintock, C. T. Main, E. P. Adams, A. D. Flinn and R. A. Hale, and they were unanimously chosen by the Society.

The thanks of the Society were voted to the following gentlemen for courtesies extended to its members on the occasion of the visit to the Boston and Oxford Exchanges of the New England Telephone and Telegraph Company: Messrs. Thomas Sherwin, J. N. Keller, I. H. Farnham, C. J. H. Woodbury, G. K. Mason and F. L. Gilman.

On motion of Mr. A. H. French it was voted that the annual dinner of the Society be held on the evening of February 7, 1899, as proposed by the Board of Government, that Mr. Henry Manley be a committee of one,

with full powers, to arrange for the dinner, and that the sum of $50 be appropriated for the incidental expenses of the same.

Mr. A. T. Safford, for the committee appointed to prepare a memoir of Col. James Francis, submitted its report, which was read and accepted.

Mr. L. M. Hastings then read the paper of the evening, entitled "Experience in Sewer Construction." The paper was discussed by Messrs. G. A. Kimball, H. D. Woods, T. H. Barnes, E. S. Dorr, A. H. French, Desmond FitzGerald and others.

Adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of Cincinnati.

CINCINNATI, O., JANUARY 19, 1899.—The 102d regular meeting of the Club was held in the rooms of the Literary Club, being called to order at 8.10 P.M.; President Hazard in the chair.

There were twenty members present, also twenty-five members of the Ohio Society of Surveyors and Civil Engineers and visitors.

The Ohio Society has been holding its annual convention in Cincinnati during the week and arrangements had been made to entertain its members in the shape of a joint session at this meeting.

The reading of the minutes and the transaction of routine business were dispensed with.

Hon. Martin Dodge, director of the Bureau of Road Inquiry, delivered an address on "Better Roads and the Free Delivery of Mail," and Professor L. A. Bauer, of the University of Cincinnati, read a paper on "The Magnetic and the Boundary Work of the Maryland Geological Survey."

A buffet luncheon was served after adjournment.

J. F. WILSON, *Secretary.*

Louisiana Engineering Society.

NEW ORLEANS, SATURDAY, JANUARY 14, 1899.—The annual meeting of the Louisiana Engineering Society was called to order this date at 8.20 P.M. by President S. F. Lewis, with seventeen members and eight guests present. The minutes of the last meeting were read and approved, and the minutes of the Board of Direction were also read for the information of the members.

The report of the Board of Direction, embodying the reports of the Outing Committee, Library Committee and Librarian, Secretary and Treasurer, was read and ordered filed.

Upon the attention of the meeting being called to the fact that our February meeting is scheduled for February 13, which happens to be the eve of Mardi Gras, it was resolved that it be postponed one week.

It being next in order the President read his annual address, which was profusely illustrated with lantern slides. It was most heartily applauded.

A recess of ten minutes was taken preparatory to the election of officers, after which, upon being called to order, the following officers were elected for 1899:

President—Thomas L. Raymond.

Vice-President—C. H. Chamberlin.

Secretary—J. F. Coleman.

Treasurer—Alf. F. Theard.

Mr. H. J. Malochee was elected as Director for a three-year term, vice Mr. F. T. Llewellyn, whose term has expired. Mr. Sidney F. Lewis was elected as representative on the Board of Managers of the Association of Engineering Societies for 1899. Mr. Raymond resigned from the Directorship in order to accept the Presidency, and the vacancy thereby created was announced, to be filled at the next regular meeting of this Society.

The thanks of the Society were extended Mr. Lewis by motion for his instructive address. And upon motion, duly seconded, it was resolved that the thanks and appreciation of the Louisiana Engineering Society be expressed to Mr. Sidney F. Lewis for his very able administration of its affairs during his term of office.

Adjourned.

J. F. Coleman, *Secretary.*

Montana Society of Engineers.

At the regular monthly meeting of the Society, held in Helena, Montana, on December 10, 1898, the fore part of the evening was devoted to business matters, after which a paper by Mr. Francis W. Blackford, upon his construction of the Butte-Centerville Electric Railway, was read and discussed.

A vote of thanks was extended to Mr. C. B. Nolan, Attorney-General of Montana, for his kindness in examining and giving his legal opinion upon the bill providing for a State Engineer; also to Mr. F. W. Blackford for his instructive paper.

A. S. Hovey, *Secretary.*

Detroit Engineering Society.

Detroit, Mich., January 24, 1899.—The thirty-sixth regular meeting of the Society was held at the Hotel Ste. Claire, Friday, January 20, 1899, at 8 p.m.

Mr. W. J. Keep, First Vice-President, was in the chair, and Mr. Henry Goldmark was Secretary. There were twenty-five members and guests present. The Executive Committee reported the following names of gentlemen proposed for membership, viz.: Mr. C. B. Stewart, Assistant Engineer U. S. Board of Engineers on Deep Waterways, Detroit; Mr. G. B. Mitchell, with the same Board.

The paper of the evening, on "Overhead Electric Conductors," was read by the author, Mr. Alex. Dow, general manager Edison Illuminating Company, of Detroit. It was discussed by Messrs. Steele, D. A. Molitor, Demrick, Field, Phillips and Dow, and by Mr. G. P. Nichols, of Chicago.

Adjourned.

The Executive Committee met at the Hotel Ste. Claire, January 20, 1899. Present, Messrs. Keep, Dow and Goldmark.

The names of Messrs. C. B. Stewart and G. B. Mitchell were proposed for membership.

Bills of Richmond & Backus Co. and of Henry Goldmark were approved.

Adjourned.

Henry Goldmark, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, January 6, 1899.—Called to order at 8.30 p.m. by Vice-President Percy.

The minutes of the last regular meeting were read and approved.

On motion the action of the chairman of the Finance Committee and the Secretary in paying the sum of $20 on account to George Spalding & Co. was approved.

Mr. C. E. Grunsky offered the following amendent:

"*Resolved*, That Section 1 of Article VII of the By-laws be amended to read as follows:

"Add to the said section the words:

"*Provided*, That persons eligible to membership who are temporarily stationed on the Pacific Coast shall be exempt from the payment of an admission fee."

The resolution was accepted and ordered voted upon at the next regular meeting according to the by-laws.

The following report of the Nominating Committee was read by the Secretary:

Your committee respectfully reports that it has made a careful canvass of the available names, and has been authorized by all of them in the ticket named below to report that if elected they will serve the Society in the offices as follows:

President—George W. Percy.

Vice-President—Hubert Vischer.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Louis Falkenau, T. W. Ransom, S. C. Irving, Hermann Barth, T. W. Brooks.

Respectfully submitted,

Luther Wagoner, *Chairman*.

The report was ordered accepted, and the Secretary instructed to prepare the necessary ballots for the election of officers to be held January 20.

The chairman appointed the following judges of election in accordance with Section 2, Article II of the By-laws: Luther Wagoner and D. C. Henny.

The Secretary was furnished with a list of available candidates for membership, and instructed to communicate with these gentlemen for the purpose of obtaining their names to increase the Society's membership.

Adjourned.

Otto von Geldern, *Secretary*.

Annual Meeting, January 20, 1899.—Called to order at 8.30 p.m. by President Molera.

The minutes of the last regular meeting and the last annual meeting were read and approved.

Messrs. Luther Wagoner and D. C. Henny, tellers appointed to count the ballots for officers for the ensuing year, announced the following ticket elected:

President—G. W. Percy.

Vice-President—Herbert Vischer.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Hermann Barth, Louis Falkenau, T. W. Ransom, Samuel C. Irving, Thomas W. Brooks.

The report of the Treasurer was read and ordered received and placed on file. The Secretary was granted two weeks further time to complete his annual report.

The resolution by Mr. C. E. Grunsky, proposed at the last regular meeting, that the by-laws be amended so as to admit professional men who may be temporarily stationed on this coast as members without the payment of an admission fee, was adopted upon motion. The Secretary was instructed to so modify the present by-laws as to show this clause, by pasting the slips containing the change between the proper leaves; also to send to each member of the Society the printed slip calling attention to this modification.

The Secretary was likewise instructed to write to the Secretary of the Association of Engineering Societies, requesting him to inclose a mailing list, showing the present membership of the Technical Society, to each member with the next circulation of the JOURNAL.

The application of Mr. F. C. Herrmann to become a member was referred to a regular monthly meeting of the Society.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 2, 1899.—The sixteenth annual meeting of the Civil Engineers' Society of St. Paul was held at 8.15 P.M. Nine members present. President Estabrook in the chair. Minutes of previous meeting read and approved.

Communications were acted upon as follows: From League of Associated Engineers and Albert Blauvelt, circulars and copy of H. R. 10,403 as to reorganization of naval personnel. Referred to committee, Powell, Münster and Annan, with power to act.

From J. J. R. Croes, letter transmitting various copies of reports, Librarian to file reports and Secretary to thank Mr. Croes.

From Secretary of the Association of Engineers of Virginia, letter announcing formal disbanding of Association.

Copy of Municipal and Railway Record referred to Librarian for examination.

The annual reports were read and accepted.

The Treasurer was authorized to pay $10 for care of Society room, and the Secretary was instructed to write a letter of thanks to the joint commission for courtesies extended. The officers of the Society were reelected and Mr. George L. Wilson was elected representative on the Board of Managers of the Association of Engineering Societies.

C. L. ANNAN, *Secretary.*

Civil Engineers' Club of Cleveland.

CLEVELAND, O., JANUARY 10, 1899.—The regular monthly meeting was held in Case Library January 10, at 8 P.M., with Past-President James Ritchie in the chair; present thirty-four members and five visitors. On motion of Mr. Culley the reading of the minutes was dispensed with and the minutes as printed were approved.

Messrs. Culley and McIntyre were appointed tellers to canvass ballots for members, and on receiving their written report the chair announced the election to active membership of Frederick Metcalf and Charles Olney Cook.

The Executive Board reported favorably upon the applications for active membership of Messrs. William Oswald Henderer, Wilbur Jay Watson, Ransome Tedrowe Lewis and William Martin Torrance.

Under the head of correspondence a letter received from the Civil Engineers' Society of St. Paul was read, showing that the Society had referred to a committee the subject of the reorganization of the naval personnel.

The committee appointed at the last regular meeting to investigate the question of new quarters made its report as follows:

REPORT OF SPECIAL COMMITTEE ON QUARTERS.

To the President and Members of the Civil Engineers' Club of Cleveland:

At the beginning of its investigations into the "feasibility of renting quarters in the new building of the Chamber of Commerce" your committee was confronted by the fact that no move of that kind could be made without increasing the income; and, to that end, a circular (a copy of which is hereto appended) was prepared and sent to each of the members.

The financial statement in this circular is based on the receipts and expenditures of the last fiscal year. Of the expenditures, two items, at least, are believed to admit of considerable reduction. The JOURNAL costs $480 per year, and it is believed this can be reduced one-half by securing advertising.

The item for printing is believed to be fully fifty per cent. more than the strictly necessary requirements of the Club call for.

Sixty-four responses, all favorable, have been received to this circular, of which four are from associate members, and four are conditional. Of the remaining number fifteen are out of town, and sixty-nine have expressed no views, in writing. Of these sixty-nine the committee are of the opinion, from information gained by interviews, and otherwise, that forty-six are either in favor of the proposition, or at least are not actively opposed to it; of twenty-three no opinion of any kind could be formed. Five members only have expressed opposition, based in every case, on the increase of the dues, and in one or two cases on the prospective severing of our relations with Case Library.

So far as the latter objection is concerned the committee believe that it can be easily removed. Two courses are open to the Club; one to continue the present arrangement, as to the purchase of books, with Case Library, the other for the Club to undertake the accumulation of a reference library of its own.

The committee did not consider it within the scope of its duties to investigate this question exhaustively, and therefore has no recommendation to

make in this connection. As to the objection to the increased dues, the committee is of the opinion that the benefit to be derived is very much greater in proportion than the increase in the dues. A large proportion of the members feel that they are not getting benefits at all commensurate with the present dues, and it is believed that a good deal of this dissatisfaction would be removed by acquiring commodious, well-furnished quarters that would always be available, exclusively to members. The privilege of the chamber restaurant and the identification of the Club, to a certain extent, with the chamber, are believed to be advantages that will appeal forcibly to our more progressive and active members and to many whom we hope to enroll if this proposition be adopted.

A suggestion has been made that an assessment of $5 be levied in lieu of amending the constitution. In favor of this it may be said that in the event of a large accession of members or of an unforeseen reduction of expenses it might not be necessary to increase the dues at all; but, on the other hand, it may be urged that assessments, in general, are impolitic, and that the members will receive benefits fully commensurate with the increased dues. Any surplus, too, could always, under good management, be used to good advantage to increase still further the benefits to the members.

The committee does not consider the securing of new quarters to be a panacea for all the ills from which the Club is suffering. These evils are due to the dry rot engendered by the total indifference of a large proportion of the members for a long time past, and as to the cause of which your committee expresses no opinion. It is the opinion, however, that the securing of the new quarters in question will be a long step toward improved conditions; and that then, with a management which shall seek and put into effect every practicable idea for the betterment of the Club, and with the hearty and united co-operation of all its members, the Club will become what it ought to be, the recognized authority on all questions pertaining to the profession in this city, and a body to which every one of its members will feel it an honor and a privilege to belong.

As the option which has been secured on these rooms expires to-morrow, and as these rooms, at the very longest, will not probably be available longer than for a few days, your committee respectfully recommend the adoption of a resolution at this present meeting looking to the closing of an agreement with the Chamber of Commerce looking to the renting of these rooms.

Jos. C. Beardsley,
W. R. Warner,
W. B. Cowles,
Committee.

January 10, 1899.

CIRCULAR.

December 20, 1898.

To the Members of the Civil Engineers' Club of Cleveland:

Your attention is respectfully requested to the following statement and proposition respecting new quarters for the Club:

If action be taken *at once,* rooms can be secured in the new building of the Chamber of Commerce. The use of these rooms will include the use of the smaller auditorium of the chamber (known as the council room), when necessary, and the privilege of the chamber restaurant.

The rooms which your committee consider most desirable are on the fifth floor next to the Society for Savings Building, are three in number, containing about 1150 square feet of floor space, and costing $1200 per year. The smallest of these might be used for the office of the Secretary, as contemplated in the annexed financial statement. The largest is large enough for all the usual meetings of the Club, and the third could be used for a library and reading room.

The advantages of this change for the Club are that it secures a home (which it has never so far had) in the most central and easily accessible locality in the city.

We should have all the benefits and advantages of a first-class club at a trifling advance over our present dues and without any of the uncertainty and care incident to maintaining a club house of our own. Arrangements could no doubt be made to have lunches served in our own rooms after meetings, etc., if it should seem desirable.

In view of the arrangement contemplated to be made as to the Secretary, it would not be necessary to hire an attendant to look after the room, all janitor service being rendered, without extra charge, by the chamber. Each member will be provided with a key to the rooms.

It is believed that all this can be secured by increasing the dues $5 per year, and an amendment to the constitution to this effect will be introduced at the January meeting.

As the time during which these rooms will be available is limited, your committee believe that the only way to secure this opportunity is for the members individually to agree to pay for one year the amount necessary in excess of the present dues. If a sufficient number are willing to do this it follows that the success of the amendments is assured.

The financial statement and estimate appended is based on the last annual reports of the Secretary and Treasurer.

RECEIPTS.		
General (dues)	$1,598 44	
Permanent (entrance)	172 05	
Library (voluntary subscription)	120 00	
		$1,890 49
EXPENSES.		
Rent and lighting	$1,250 00	
Journal	480 00	
Printing (omitting banquet)	337 45	
Stationery	46 07	
Postage and express	88 35	
Memorials and certificates	45 90	
Allowance to Secretary to cover clerical work in addition to use of office allowed him for his personal business	100 00	
Incidentals	52 23	
		$2,400 00
Annual allowance for furniture and fixtures (permanent fund)	170 00	
Annual allowance for library based on last year's subscriptions	120 00	
		290 00
Total expenses		$2,690 00

Leaving a deficit of $800, which may be met as follows:

150 active members at $5	$750 00
20 associate members at $5	100 00
Total	$850 00

Leaving a margin of $50 for contingencies.

This statement excludes all items of the social account. The permanent fund, amounting on March 1, 1898, to $722, is available for the immediate needs of the Club as to furnishings.

J. C. Beardsley,
W. R. Warner,
W. B. Cowles,
Committee.

Mr. Culley moved that the report be received. This was seconded.

Mr. Beardsley moved as an amendment that the report be received and adopted.

Professor Langley offered as a further amendment that the report be laid on the table. This amendment was lost.

A discussion ensued on Mr. Beardsley's amendment in which Messrs. Baker, Beardsley, Culley, Hopkinson, Hyde, Parmley, Skeels and Professor Langley took part. On calling for the question there were thirteen ayes and twelve nays, and on the adoption of the original motion there were fourteen ayes and thirteen nays, and the chair declared the report adopted.

Under the head of miscellaneous business the question of the proper action of the Club on the committee's report was discussed. It was moved by Mr. Beardsley that the Executive Board be authorized and directed to enter into an agreement with the Chamber of Commerce for the renting of the three rooms which have been in question during this discussion.

Mr. Culley offered as an amendment that the question be submitted to letter ballot, to be canvassed at the semi-monthly meeting in January. This amendment was seconded and fully discussed. On being put to vote it was lost.

The original resolution, having also been discussed while the amendment was pending, was then put to vote, and was adopted by fifteen ayes and eleven nays.

The Club then proceeded to choose a Nominating Committee to report a ticket for the coming year. The following names for the committee were offered by different members present: John L. Culley, Joseph C. Beardsley, William B. Cowles, A. Lincoln Hyde, Harry A. Nelson, Samuel J. Baker, Walter C. Parmley. No other names being offered, on motion the nominations were declared closed, and it was voted that the seven members named should constitute the Nominating Committee.

The hour being late, Mr. Hyde, seconded by Mr. Cowles, moved that the paper of the evening be postponed to the regular meeting in February in order that proper justice might be done to the subject. The motion was carried. The Club then adjourned at 10.15 for conversation and lunch.

William H. Searles, *Secretary.*

The semi-monthly meeting was held in Case Library, Tuesday, January 24, at 8 p.m.; present nineteen members and six visitors; President Osborn in the chair. Mr. William B. Cowles, member of the Club, read

the paper of the evening, entitled "The United States Navy; Personnel Reorganization its Greatest Need." He gave a brief glance at the history of our navy, showing its greater relative importance in the earlier days of the republic until the development of the vast interior of our country absorbed our attention and drew largely upon our resources. The latest statistics show the United States Navy to rank fifth in the world by tons displacement, while its merchant marine ranks second. The material of our navy is excellent, but the quantity is far too small. The author described the nine corps among which the naval officers are distributed and referred to the differences existing under the present law between the line and staff, particularly between the line and engineers. These differences in rank cause needless incongruities and complications in duty and unjust postponement of promotion, while the differences in pay are unjust alike to the juniors of the line and the seniors of the engineers. The bill (H. R. 10,403) now pending in Congress will unquestionably cure these and many other existing evils and give to our navy a homogeneity and efficiency unequaled in the world.

The paper was earnestly discussed, and a resolution was adopted advocating the passage of the bill in question.

At 10.30 the Club adjourned and lunch was served.

William H. Searles, *Secretary.*

Association of Engineering Societies.

Vol. XXII. FEBRUARY, 1899. No. 2.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Regular Meeting, February 14, 1899.—The regular monthly meeting was held in Case Library on February 14, 1899, at 8 P.M.; President Osborn in the chair. Present, thirty-two members and seventeen visitors. On motion, the reading of the minutes of the January meetings was dispensed with.

Messrs. C. O. Palmer and H. S. Nelson were appointed tellers to canvass ballots received. They reported the election to active membership of Messrs. William Oswald Henderer, Wilbur Jay Watson, Ransome Tedrowe Lewis and William Martin Torrance.

The Executive Board presented the name of Allan Wadsworth Carpenter as candidate for active membership. The board reported that action regarding leasing rooms of the Chamber of Commerce had been deferred until a reply was made to a tender for joint use of rooms, made by the board to the Electric Club. The board recommended that the annual banquet be omitted this year, and that a social function be held instead in the new rooms of the Club when opened.

A letter from the Electric Club was read, in which a proposition to rent jointly four rooms on the sixth floor of the Arcade was submitted.

The Committee on Rooms made an informal report. The Committee on Nominations reported the following ticket to be voted on in March:

For President—Col. Jared A. Smith.

For Vice-President—Dr. John W. Langley.

For Secretary—Arthur A. Skeels.

For Treasurer—John N. Coffin.

For Librarian—William E. Reed.

For Directors, two years—Joseph R. Oldham, William B. Hanlon.

On motion, the report was received.

Mr. A. L. Hyde moved a reconsideration of the vote of the Club at the last regular meeting upon the motion of Mr. Beardsley authorizing and instructing the Executive Board to enter into an agreement with the Chamber of Commerce for the renting of three rooms. The reconsideration was ordered.

Mr. Hyde moved that Mr. Beardsley's motion be laid on the table. Seconded and carried.

Mr. Hyde, seconded by Mr. W. B. Cowles, moved that the Committee on Rooms be enlarged by the addition of four names, and that its duties be extended to include the consideration of rooms elsewhere than in the Chamber of Commerce building. Carried. The President named Messrs. L. B. Hoit, Wm. E. Reed, John N. Coffin and C. W. Hopkinson to be added to this committee.

Professor Robert H. Fernald read the paper of the evening, "Experiments on the Efficiency of Bicycles," describing investigations made at the Case School of Applied Science, and giving certain conclusions arrived at. Comparisons were drawn between chain and chainless bicycles, racing and road wheels, between sprockets of different size, and tires under different air-pressures. Diagrams showing relative efficiency were exhibited.

The subject was discussed by Dr. Langley, Professor Benjamin, Mr. S. T. Dodd and others.

Mr. Hyde moved that a banquet committee of seven be appointed. Seconded and carried.

Mr. Reed moved that the committee use its discretion as to having a banquet or reception. Seconded by Mr. Beardsley and carried. The President said he would announce the members of this committee later.

The President announced that the members and visitors present were invited to inspect the rooms of the Board of Underwriters in the Arcade, which are for rent, and then to take lunch at Stranahan's.

Adjourned at 9.30 P.M.

WILLIAM H. SEARLES, *Secretary.*

NOTE.—On February 23 the President appointed Messrs. James Ritchie, S. Lincoln Hyde, Aug. Mordecai, John R. Richardson, Dr. Perry L. Hobbs and Edwin S. Mills as a Banquet Committee.

SPECIAL MEETING, CLEVELAND, FEBRUARY 28, 1899.—The semi-monthly meeting was called to order at 8.15 P.M.; Past-President Ambrose Swasey in the chair. Present, thirty-three members and two visitors. The minutes of the last meeting were read and approved.

The report of the Committee on New Quarters having been made the special order for this meeting was called for. The chairman, Captain Beardsley, stated that he had but a part of the papers with him, Mr. Reed having the rest of them, and he had not yet arrived. Mr. Ritchie moved that the report be now read. This was seconded, and on being put to vote was lost.

Mr. Joseph R. Oldham then read the paper of the evening on "The Rise and Fall of the American Merchant Marine," which abounded in interesting facts as to the past and glowing anticipations for the future. The subject was discussed by Messrs. Howe, Green, Culley, Searles and the author.

The report of the Committee on New Quarters being again called for, its chairman stated that the committee had been unable to agree upon a report, and consequently had none to make. It had held several meetings, but had come to no conclusion. At a joint meeting of the committees of this and other technical societies of Cleveland two plans had been proposed, and a resolution in favor of each adopted by the Joint Committee, which he then read, and submitted to the Club.

Mr. Culley, seconded by Mr. Hyde, moved that the report of the Joint Committee be received. Carried.

Mr. Ritchie, seconded by Dr. Howe, moved that the report be taken up by sections and discussed. Mr. Hyde moved as an amendment that the Club consider the two resolutions of the joint committee. It was so ordered, and the motion as amended was carried.

Dr. Howe moved, as to the first resolution, that it is the sense of this meeting that it would be unwise at present to discuss an amalgamation of the technical societies of Cleveland. Seconded and carried.

Mr. Culley moved that the Club approve of the second resolution of the Joint Committee, and that the President appoint a committee of five to carry out the plan submitted. Seconded by Mr. Hopkinson.

Mr. Parmley objected that the duty of the committee was to report on rooms and not on a plan of federation.

Mr. Hyde said its duty was also to get at the sentiment of the other societies on the subject.

Captain Beardsley said his committee had been unable to agree on a location for new quarters.

Mr. Hopkinson was in favor of confederating with other societies in accordance with the plan submitted.

Mr. Searles spoke in favor of the Club taking quarters of its own at once, because it greatly needs them, and is abundantly able to pay for them without making any assessment, and without the assistance of other societies; leaving the question of federation to be solved at leisure in the future. The experience of this committee shows how difficult it may be to bring all four societies to a common conclusion, or to a harmonious management in common quarters.

Mr. Warner objected to the last remarks, and believed that the scheme was feasible as a business proposition.

Dr. Langley quoted the experience of the Society of Engineers of Pittsburg, where a plan of federation with other societies had succeeded well, and an entire house had been occupied by them.

Dr. Howe spoke of this plan as the first one of the several heretofore considered that seems to give prospect of success.

Mr. Coffin was opposed to federation, but favored the idea of consolidation of all into a new body with one central management.

Mr. Oldham thought federation was unnecessary if this Club would take the lead as the oldest and strongest of them all. Its constitution was broad enough to include the members of the others if they were inclined to come in. Only let us get rooms of our own.

Dr. Howe objected to the clause in the plan offered which provides that the members of each society be associate members of each of the other societies, and moved as an amendment that this clause be struck out. Amendment agreed to by Culley and Hopkinson.

Mr. Ritchie said it would be unconstitutional for this Club to create a Board of Directors as provided in the plan.

Dr. Howe explained that the proposed board was for the purpose of managing the joint property of the federation; it was a business proposition merely, and did not disturb the internal affairs of either society.

After further discussion the question was put to vote and carried. On motion the Club then adjourned at 10.30 P.M., before the President had time to announce the committee provided for in the resolution.

The plan and resolution, as approved by the Club, reads as follows:

Skeleton plan for the federation of the scientific societies of the city of Cleveland:

SOCIETIES TO BE ASSOCIATED.

The Civil Engineers' Club of Cleveland.
The Electric Club of Cleveland.
The Cleveland Architectural Club.
The Cleveland Chemical Society.
and such other technical societies as may wish to join.

OBJECTS TO BE GAINED.

Mutual improvement, wider acquaintance, closer relationship, broader views, more weight in the community, common quarters, better and larger attendance of all meetings, and as a result better papers prepared with more care, better general results without increased expense.

FINANCES.

Expense of hiring commodious quarters with suitable custodian or clerk and the issuing of a bulletin giving dates of meetings, titles of papers and other information of general interest to be borne jointly by the societies interested and in the ratio of their memberships. This expense not to exceed $4 per capita per annum.

INDIVIDUALITY.

Each society to retain its present individuality as regards its name and constitution and by-laws, the latter to be so amended as not to conflict with the objects to be gained.

MANAGEMENT.

The affairs of the federation to be managed by a Board of Directors made up from the societies represented in the ratio of one representative for each fifty active members or fraction thereof, of the respective societies, together with one member at large from each society.

Resolved, That it is the sense of this Joint Committee that the plan herewith submitted for a joint occupancy of room, if approved by the membership of each of the four societies represented on the committee, can be speedily arranged.

WILLIAM H. SEARLES, *Secretary*.

Technical Society of the Pacific Coast.

REGULAR MEETING, FEBRUARY 3, 1899.—Called to order at 8.30 P.M. by Past-President Molera.

The minutes of the last regular meeting and of the annual meeting were read and approved.

The following associate members were declared elected by ballot: Joseph F. Forderer, of Alameda, and John J. Mahoney, of San Francisco.

Three applications for membership, Herman, Fraser and Ballantyne, and five applications for associate membership, Butcher, Day, McPhee, McGilvray and Masow, as laid before the Board of Directors, were read and ordered to take the usual course.

Past-President Molera then addressed the Society, reviewing briefly the work done and the efforts made during the past year, reverting at length to the financial standing and to the absolute necessity of raising a fund of $400 to liquidate the long-standing indebtedness of the Technical Society. Half the sum, he stated, had been realized by obtaining two life members upon a payment of $100 each, and it remained for the members

to raise the amount of $200 only. He made the proposition that if the individual members would start a subscription for voluntary contributions, he would agree to pay the balance of what such contribution might lack to complete the sum required.

Mr. Grunsky moved that any contribution made by a member, together with the dues for 1899, shall be construed as a payment on a life membership, should the member conclude to become one during this year. Seconded and carried. The following contributions were then offered: G. W. Percy, $10; E. J. Molera, $10; Hubert Vischer, $10; A. J. McNicoll, $10; Otto von Geldern, $5; Hermann Barth, $5; T. W. Brooks, $10; S. C. Irving, $10; Adolf Lietz, $10; E. T. Schield, $10; A. D'Erlach, $5; C. E. Grunsky, $10; total, $105.

It was ordered that the list be kept open until the next regular meeting for further voluntary contributions.

Mr. Molera introduces the President-elect, Mr. Percy, who takes the chair, congratulates the members and thanks Mr. Molera for his generous offer and constant assistance to place the Society upon a firm footing.

The report of the Secretary, including that of the Treasurer, for the year 1898, was read and ordered received and placed on file.

A communication from Prof. W. B. Rising, of the University of California, was read, in which he requests the Society to assist him in securing samples of fuels of the Pacific Coast, and in gathering certain data as to the evaporation test, and for the determination of the absolute heat value, etc.

Upon motion, it was ordered that a committee of three be appointed to give Professor Rising any assistance possible in this line, and that the Secretary be instructed to communicate with him and to inform him of the action of the Society. The chair thereupon appointed the following committee: Luther Wagoner, John Richards and H. C. Behr.

Mr. Grunsky read a letter from Mr. F. H. Newell, Hydrographer United States Geological Survey, calling attention to an act authorizing the appointment of a Commissioner of Irrigation by the State, to co-operate with the Director of the United States Geological Survey in surveys and estimates of costs of reservoirs for storing flood waters for irrigation, mining and industrial purposes, and appropriating money to carry out the provisions of this act.

The Secretary then proceeded to read the act, consisting of seven sections, after which a short discussion followed without action.

Mr. Grunsky spoke of the proposed effort to remodel the State Board of Harbor Commissioners, and referred to the apparent necessity of certain changes in its administrations.

Adjourned.

OTTO VON GELDERN, *Secretary*.

DIRECTORS' MEETING, FEBRUARY 3, 1899.—Called to order at 4.15 P.M. by President Percy. Present, Directors Percy, Vischer, Ransom, Irving, Barth and von Geldern. The chair appointed the following committees:

Executive—Vischer, Falkenau and Brooks.

Finance—Barth, Ransom and Irving.

As Managers on the Board of the Association of Engineering Societies Messrs. D. C. Henny and Otto von Geldern were appointed by the chair.

The Secretary was instructed to write to Prof. Frank Soulé to make inquiry as to the present status of the Committee on Pacific Coast Timbers.

The following applications for membership were made and ordered to be read at the regular meeting of the evening:

For members:

1. A. B. Ballantyne, Superintendent of Lighthouse Construction, San Francisco. Proposed by Otto von Geldern, Hubert Vischer and C. E. Grunsky.

2. F. C. Herrmann, civil engineer, Gilroy. Proposed by C. E. Grunsky, Otto von Geldern and H. C. Behr.

3. E. M. Fraser, electrical engineer, San Francisco. Proposed by Hermann Barth, A. J. McNicoll and G. W. Percy.

For associate members:

1. John D. McGilvray, contractor, Palo Alto. Proposed by Hermann Barth, G. W. Percy and Otto von Geldern.

2. Frank H. Masow, builder, San Francisco. Proposed by G. W. Percy, S. C. Irving and Otto von Geldern.

3. Daniel McPhee, contractor, San Francisco. Proposed by S. C. Irving, G. W. Percy and Otto von Geldern.

4. Charles A. Day, builder, San Francisco. Proposed by S. C. Irving, T. W. Ransom and Otto von Geldern.

5. Thomas Wm. Butcher, builder, San Francisco. Proposed by Hermann Barth, T. W. Ransom and S. C. Irving.

No further business appearing, the meeting adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

484th Meeting, February 1, 1899.—The meeting was called to order at 8.15 p.m.; President Colby in the chair. Twenty-seven members and eight visitors were present.

The minutes of the 482d meeting were read and aproved. The minutes of the 269th meeting of the Executive Committee were read. The application of Mr. H. S. Wilson having been approved by the Executive Committee, he was balloted for and declared elected a member of the Club. The applications for membership of Mr. George A. French and Mr. Charles A. Tripp were announced. The resignation of Prof. J. B. Johnson as a member of the Board of Managers of the Association of Engineering Societies was read and accepted, as was the resignation of Mr. Elliott Jones as a member of the Club.

The donation of "The Science of Modern Cotton Spinning" in two volumes by Messrs. T. G. Meier and E. D. Meier, and Vol. XXVII of the Transactions of the American Institution Mining Engineers by Mr. E. D. Meier, were announced, also some reports on Water Supply and Sewerage by Mr. J. James R. Croes.

Mr. H. S. Wilson then read the paper of the evening, entitled the "Production of Seamless Tubing." Mr. Wilson dealt with the kinds and characteristics of the ore needed and some of the requisite processes of its reduction to make the grade of steel necessary for drawing seamless tubes. The various methods of getting the hole in the billet were explained and the main characteristics of the more important machines used for this purpose were set forth.

The annealing and pickling processes were described and the delicacy of the operation shown. The drawing benches, with their attendant drawing devices, the number of reductions necessary, the kinds of lubricants used, etc., were all fully gone into, and interesting reasons for many troubles which arise given. Mention was made of the great variety of grades and sizes of tubes and the care necessary to keep them separate in the factory. The processes for the production of lead, brass and copper tubes were also touched upon. Sketches on the blackboard illustrated graphically and clearly the various points and a few samples showed how the reductions are made. There being no further business, the meeting adjourned to another room, where a light lunch was served.

E. R. Fish, *Secretary.*

485th Meeting, February 15, 1899.—The meeting was called to order at 8.20 p.m.; President Colby in the chair. Forty-three members and twenty visitors were present. The minutes of the 484th meeting were read and approved. The minutes of the 270th meeting of the Executive Committee were read. The names of Messrs. V. K. Hendricks, H. B. Shaw, W. A. Bennett and F. F. Astell were proposed for membership. Messrs. Chas. A. Tripp and George H. French, having been recommended by the Executive Committee, were balloted for and declared elected members of the Club. Messrs. Bryan, Laird and Connor were nominated as a member of Board of Managers of the Association of Engineers Society. Vote was taken by ballot, and Mr. Bryan was declared elected to the position, the vote being Bryan, 27; Laird, 8; Connor, 8; McCulloch, 1.

Mr. M. L. Holman then opened the discussion of the evening on the Chicago Drainage Canal, giving a brief description of main features of Chicago's sewerage system, the Chicago River and the canal itself. He also read parts of the law, giving the provisions for the construction and taxation to pay for it.

Mr. R. E. McMath further elaborated the subject, showing the relation of the Desplaines River, the Illinois and Mississippi Canal and the Drainage Canal. He also discussed some of the early attempts of Chicago to gain relief from the sewerage. The effect of the canal in a commercial way was touched upon.

Mr. Holman added some further remarks on the engineering fallacies of the scheme as undertaken. He stated that the original plans had not been followed out and mentioned that the Chicago engineers themselves do not see the way clear to successful fulfillment of the original expectations. Mr. Colby also added a few remarks.

There being no further business, the meeting adjourned to another room, where lunch was served.

E. R. Fish, *Secretary.*

Engineers' Club of Minneapolis.

Minneapolis, Minn., February 13, 1899.—The regular monthly meeting of the Engineers' Club of Minneapolis was called to order in the parlors of Hotel Hyser, at 8.15 p.m. President Cappellen not being present, City Engineer G. W. Sublette was elected presiding chairman of the meeting. The minutes of the last meeting were read and approved. Several letters of interest to the Club were read by the Secretary. Upon

motion of Mr. Redfield, the notice of the St. Paul Society regarding the trip of inspection of the Bronsdon Car Raising Device, which this Club participated in, was spread upon the minutes of the Club.

Prof. G. D. Shepardson then read his annual report as member of the Board of Managers of the JOURNAL. Upon motion, the report was filed. The Treasurer then presented his annual report, as follows:

RECEIPTS.

Balance received from last Treasurer	$51 36
Cash from initiation fees, 9 new members	45 00
" JOURNAL subscriptions	6 00
Total	$102 36

EXPENDITURES.

For postage and printing	$11 03
" rooms at Hotel Hyser	12 00
" four annual assessments paid to J. C. Trautwine on JOURNAL account	32 25
" binding 8 vols. Journal of the Association Journal for Library of Club	4 80
Total	$60 10

Total cash in my hands February 13, 1899 .... $42 26

It was moved that the report be sent to the Auditing Committee. Carried.

County Surveyor G. W. Cooley then read a very interesting paper upon "A Study of the Hydrography of Lake Minnetonka."

It was moved and carried that Mr. Cooley's paper be printed in the JOURNAL. As the hour was getting late it was decided to postpone the election of officers until the following meeting.

There being no further business, the meeting was adjourned.

HARRY E. SMITH, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, FEBRUARY 7, 1899.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8 P.M. Present thirteen members and one visitor. Minutes of previous meeting read and approved. A verbal report of Committee on Naval Personnel Bill was accepted and committee discharged. President Estabrook then called on Mr. Hogeland, who read a paper on "Locomotive Coaling Stations." He illustrated by drawings and photographs the evolution of coal handling for locomotive use on the Great Northern Railway. Beginning with the primitive derrick and bucket system, which was worked at an expense of 17 cents per ton, he advanced through various stages (1) shoveling into chute pockets; (2) dumping and chain conveying to chutes; (3) dumping directly into chute, coal car being raised by 15 H. P. gasoline engine. The Great Northern moves 750,000 tons annually through chute pockets of five or six tons capacity at an average cost of 3 cents per ton by measurement. Mr. Truesdell followed Mr. Hogeland with a description of im-

provement at the South St. Paul stock yards, 172 acres in extent, bounded on the river side by $1\frac{3}{4}$ miles of levee. The level of the yards is several feet below high-water mark, and has been flooded to the depth of 3 feet, but now the five sewer outlets may be closed by gates, and pump wells have been provided in case of flood. Nine artesian wells supply water. Swift & Co.'s immense packing establishment and half a dozen minor concerns do a rushing business on the site. An electric lighting plant turns night into day when necessary. Mr. Wilson having in the meantime arranged a vast exhibit of asphalts, crude and refined, rock plaster and semi-liquid, passed around prints and photographs and proceeded to say a few words on the sources of American asphalts. Trinidad, Bermudez, Kentucky, California and Utah deposits were considered physically, chemically and geologically, but briefly, as the hour was late.

C. L. ANNAN, *Secretary.*

Detroit Engineering Society.

THE thirty-seventh regular meeting of the Society was held at the Detroit Art Museum, Friday, February 24, 1899, at 8 P.M. A large number of invitations was sent out, and the presence of ladies was specially requested. The audience numbered about two hundred.

Mr. Geo. Y. Wisner, President of the Society, presided. Messrs. C. B. Stewart and G. B. Mitchell were elected as members.

The paper of the evening was then presented by the author, Mr. B. S. Colburn, erecting engineer of the Detroit Bridge and Iron Works. Its title was "The Erection of the Victoria Jubilee Bridge over the St. Lawrence at Montreal." The paper was illustrated by stereopticon views, nearly 50 in number, from photographs taken by the author, and showing all the details of the erection.

Adjourned. HENRY GOLDMARK, *Secretary.*

A MEETING of the Executive Committee was held at the Detroit Art Museum, Friday, February 24, 1899; present, Messrs. Wisner, Keep, Pope, Hinchman and Goldmark.

Bills due the following persons were approved and ordered paid:

John Bornman & Sons	$36 00
Field & Hinchman	4 59
Henry Goldmark	5 00
B. S. Colburn	10 00
Association of Engineering Societies	23 25
Adjourned.	$78 84

Montana Society of Engineers.

THE regular monthly meeting of the Society was held in its rooms, in the Union Bank Building, Helena, Montana, on February 11, 1899. Meeting called to order at 8.30 P.M.; Mr. Elliott H. Wilson in the chair. The minutes of the twelfth annual meeting were read and approved. The applications for membership of Winfield J. Flood and William Zaschke were favorably considered and the Secretary instructed to send out the

usual letter ballots. Messrs. E. C. Kinney and J. S. Keerl were appointed tellers to canvass the ballots for membership. Twenty-five votes were cast, all affirmative, and William H. Harrison, Carlisle Mason, John D. McLeod, Charles H. Repath and Charles D. Vail were declared elected. A committee, consisting of Messrs. E. H. Wilson, A. S. Hovey and C. W. Goodale, appointed at the twelfth annual meeting to report upon the feasibility of changing the headquarters of the Society, and also of holding a part of the meetings in Butte and other places during the present year, submitted their report. They recommended that special meetings of the Society be held in Butte on the second Saturday of March and the second Saturday of every two months thereafter during the present year. The report was adopted. A question arising as to what business could be transacted at these special meetings, resolutions were adopted that at these special meetings any business of the Society should be transacted or papers read and discussed the same as at any regular meeting.

The Pettigrew amendment was read and discussed.

The proposed amendment to the "Sundry Civil Expense Bill" being as follows: "55th Congress, third session, H. R. In the Senate of the United States, January 5, 1899. Referred to the Committee on Public Lands and ordered printed. Amendment intended to be proposed by Mr. Pettigrew to the bill (H. R.) making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1900, and for other purposes,—viz, insert the following: 'That the fees of a United States Deputy Surveyor for surveying, platting and certifying to a mining claim, where the claimant wishes to obtain a patent therefor, shall not exceed $30 for one claim, or $7 per day for each day actually and necessarily employed in such work.'"

The Secretary reported that 1000 copies of this amendment and circular letters had been printed and sent out by the Society. They had been sent to the members of the Society and to every United States Deputy Mineral Surveyor in the State, and in quantities for distribution outside of the State, as follows: To all the United States Surveyor-Generals, to the Denver Society of Civil Engineers and the Technical Society of the Pacific Coast; also to a few United States Deputy Mineral Surveyors in each of the Western mining States. Responses received showed that they had been thoroughly distributed. Numerous correspondence and copies of letters and petitions to Congressmen were proof of the energetic efforts of the engineers to defeat this intended class legislation.

The charges for surveying in Montana are from $10 to $15 per day. A lode claim frequently embraces from ten to fifteen locations. To make a survey of such a claim and work up the returns for the United States Surveyor-General's office would require three or four weeks' time, and would require two or three assistants. The charges of the United States Surveyor-General for merely making a copy of the returns in Montana is $30 for each location. His charges for a claim embracing ten locations would consequently be $300. Placer claims are frequently more complicated than lode claims. One of the members referred to United States Survey No. 1348, of the Turnley Placer, near Elkhorn, Mont. It has 143 courses. This was a survey of a single location, which contained 160 acres of ground. He thought that not less than two months' time would be required to make the survey and prepare the returns for the United States Surveyor-General's office.

The Government does not pay the deputy for his survey, but he is paid by the claimant, or it is in the nature of private surveying work, consequently United States Surveyor-General Beattie, of Montana, considered it class legislation and unconstitutional.

In a letter from United States Surveyor-General Penault, of Idaho, he states, "I am opposed to all legislation of this character, as it cannot apply to all classes of cases, and I cannot see any greater reason for fixing by law the compensation of a deputy for surveying a mining claim than I can for regulating the compensation for services of any other professional man."

Mr. Wilson stated, "No part of this expense or responsibility thereof is borne by the Government, the surveyor not being a salaried officer of the Government, but, as an individual, making merely a private contract with claimant.

The United States Surveyor-General issuing an order to make the survey, and approving the returns, if upon examination they are found to be correct. The work involved in these surveys differs greatly. I have devoted twenty days' arduous labor, in field and office, to one such survey; again I have completed one such survey in one day."

Deputy Chase stated, "If the bill could be enforced it would not secure the object supposed, as it would result in driving all responsible deputies out of the business."

No further business offering, the meeting adjourned.

A. S. Hovey, *Secretary.*

Engineers' Society of Western New York.

Buffalo, N. Y., February 25, 1899.—The Engineers' Society of Western New York entertained at the rooms of Builders' Exchange the Buffalo Chapter of Architects and the Society of Artists.

At our regular meeting, in Buffalo Library rooms, March 6, 1899, Mr. F. V. E. Bardol, Chief Engineer of the Department of Public Works, opened the discussion on "The Abatement of the Hamburg Canal." Owing to short notice and pressure of other work, no formal paper had been prepared, so Mr. Bardol talked informally upon the question, which manner of treatment proved to be very interesting and instructive, as many questions were presented. As many of our readers know, the abatement of the Hamburg Canal has been a question of long standing in Buffalo, and as the present plans involved an expenditure of over $700,000 they were presented to Mr. Rudolph Hering for critical examination, he having been called in by the city as consulting engineer. We are pleased to note that the plans, as prepared by Mr. Bardol, Chief Engineer, and Mr. A. W. Hoffman, Assistant Engineer, were approved in general by Mr. Hering.

H. J. March, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
CINCINNATI
ST. LOUIS
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W.VA.
MD.
VA.
KY.
TENN.
N.C.
S.C
ARIZ.
N. MEX.
OKLA.
IND. TY.
ARK.
MISS.
ALA.
GA.
TEX.
LA.
FLA.
ME.
MASS.
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC OCEAN

Association of Engineering Societies.

Vol. XXII. **MARCH, 1899.** No. 3.

PROCEEDINGS.

Montana Society of Engineers.

The twelfth annual meeting of the Society was held in Helena, Mont., January 12-14, 1899.

A meeting was held in the Chamber of Commerce rooms on January 12, beginning at 9 P.M., F. W. Blackford in the chair. After reading the minutes of the preceding meeting, and disposing of certain business matters, the bill providing for a State Engineer and defining his duties was presented by Messrs. F. W. Blackford, John Herron and F. L. Sizer, the committee who drafted it, and was read section by section and discussed.

Prof. W. H. Williams offered, as an amendment to Section 15, "And the State Engineer shall be *ex-officio* a member of the State Arid Land Commission."

Seconded by Mr. Keerl.

Mr. Keerl.—In the second Legislative Assembly a bill was introduced providing for the bonding of the State for $10,000,000, dividing it into two departments, one east of the main divide and one west, $6,000,000 to apply to the portion east of the divide and $4,000,000 to the west. That bill was submitted to the Society by the framers, and the Society's views upon it were asked. The Society naturally took a lively interest in it, and criticised it in many of its features, largely for the reason that it could not see that the State's interests were at all protected in the expenditures of such large amounts of money, in the first place, and secondly, that there was no provision made qualifying the commissioners. We took very strong grounds on that point, and the same parties that were subsequently interested in the bill that is now a law used the same general arguments,—that it was not desirable to have an engineer upon a board when they were going to employ an engineer, because it was liable to bring clashes between them. Of course we failed to see any reason in that, and said we did not know of any engineers on the railroads who had clashes with assistants, and we could see no occasion for clashes in this case. Where engineering subjects are treated in the East, the majority of those boards are engineers. They employ hundreds of engineers, and the work goes on to its final issue without any clashes whatever. The authority is vested in the board, and if the subordinate does not do his duty, he is asked to resign. When I was President of the Society I appealed personally to Governor Rickards, who was to appoint a Capital Site Commission, a Capital Building Com-

mission and the Arid Land Commission. I called upon him and stated that the engineers of the State did not think they were properly recognized in positions for which they had been specially trained. He admitted that he had been spoken to about the matter, and had given the matter some consideration, but that he had concluded it was better to appoint business men upon these commissions inasmuch as they would have to go forth and secure the money necessary to fulfill these objects. I asked him whether I was to consider that he regarded engineers as not being business men, and called his attention to the fact that my understanding of the training of an engineer was that his essential quality was to make an interest upon capital. I formed the impression subsequently that our illustrious Governor never made any appointments but for one purpose, and that for political ends, and I have since been sustained in that belief by many members of his own party. Politicians will not appoint engineers upon engineering commissions, or architects upon commission dealing in architecture, until we force them to it by exerting a political influence.

Mr. Carroll.—I agree with Governor Rickards in some of the views expressed by Mr. Keerl. I think that there is nothing more disagreeable to a chief engineer than to have on his Board of Directors an engineer. I believe that a chief engineer should have a voice in the directory if possible.

Never have an engineer on the board and a chief engineer besides. I should like very much to see the State Engineer made the chief engineer of the Arid Land Commission if it were possible, but I do not think it is. I think the same argument comes up in opposition to the bill to try to force him on this commission, and if he is a member of the commission he should be the chief engineer, otherwise he is only one of the board of three (or five?) and he is continually hampering the engineer in the discharge of his duties. This is not the case with the engineer of a railway company with his subordinates, because he looks to the directors.

Mr. Blackford.—If the Arid Land Commission chooses to employ the State Engineer as its engineer I think that it would be his duty to so act, but I do not believe it would be advisable to try to amend the Arid Land Grant bill by this bill, and make him an *ex-officio* member of that body, or their engineer.

Mr. Booth suggested that the Arid Land Commission can call at any time upon the State Engineer for any information required.

Mr. Williams, with the consent of his second, withdrew his motion.

On motion of Mr. Carroll, seconded by Mr. Williams, an amendment was adopted, providing that the Arid Land Commission shall have authority to call upon the State Engineer for such advice and professional services as they may require in the performance of their duties, and that the State Engineer shall perform such services without further compensation than the salary herein provided.

A few other amendments were made to the bill, which was then approved and handed to Hon. E. H. Wilson, member of the House of Representatives of the State of Montana, who will introduce the bill. Mr. Wilson will also introduce a bill establishing a standard of measurement for water, and defining the equivalent of a miner's inch. This bill is substantially the same as the bill drafted by A. M. Ryon (see page 87, No. 1, of Vol. XIV, 1895, of the Journal of the Association of Engineering Societies).

Since the Society, in its efforts to further needed legislation for the benefit of Montana, has devoted much time and labor to the advocacy of

the State Engineer bill it was considered desirable that said bill be published in full in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and that the Society order reprints of same.

The bill as finally approved is as follows:

HOUSE BILL No. 28.

AN ACT creating the office of State Engineer, defining his duties and regulating his compensation.

Be it enacted by the Legislative Assembly of the State of Montana:

SECTION 1. As soon as practicable after the passage of this act there shall be appointed by the Governor a State Engineer, who shall hold his office for a term of four years, or until his successor is appointed and qualified.

No person shall be eligible to such office unless he shall have had at least ten years' experience in the actual practice of the profession of civil engineering, nor unless he has such theoretical knowledge and such practical experience and skill as shall fit him for the office.

The Governor may remove such State Engineer for cause, and in case of such removal, or in case of death or resignation, shall appoint a successor.

SEC. 2. The said State Engineer shall have his office at the State Capitol, in suitable rooms to be provided for him by the Secretary of State, who shall furnish him with suitable furniture, postage, and such proper and necessary stationery, books and instruments as are required to best enable him to discharge the duties of his office.

He shall be paid a salary of $4000 per annum, payable monthly by the State Treasurer, upon warrants drawn by the State Auditor. He shall also be paid for his actual and necessary traveling expenses when away from his office on official duties.

SEC. 3. Before entering upon the duties of his office, said State Engineer shall take and subscribe an oath before some duly authorized officer, to faithfully perform the duties of his office, and shall file such oath with the Secretary of State. He shall also file with the Secretary of State an official bond in the penal sum of $10,000, with not less than two sureties, to be approved by the Governor, and conditioned upon the faithful discharge of his duties, and for delivery to his successor of all notes, maps and records of his office, and all property belonging to the State then in his possession or under his control.

SEC. 4. Said State Engineer shall have power to employ, after obtaining the consent of the Governor, one or more assistant engineers of his own selection, and such instrument men and helpers as may be necessary to economically and properly perform the duties of his office, as hereafter defined. The salary of said assistant engineers shall not exceed $150 per month each and the actual traveling expenses of such assistant engineers and helpers while away from the permanent office of the State Engineer shall be defrayed by the State.

SEC. 5. The State Engineer shall make, or cause to be made, careful measurements of the flow in cubic feet per second of the various streams in the State whose waters are, or are likely to be, appropriated and used, commencing with those streams most used for irrigation. He shall collect facts and make surveys to ascertain suitable locations for reservoirs upon streams where such reservoirs may be possible and beneficial, and shall, as far as practicable, determine the cost of constructing such reservoirs, and obtain all other facts in regard to quantity of water possible to be stored, the character and extent of land that may be reclaimed by the water from such reservoirs, together with all other information bearing upon the subject. He shall make himself familiar with the waterways and the irrigable land of the State, and the needs of the State as to irrigation matters, and all records of such information shall be the property of the State, and open to public inspection. He shall keep full and complete records of all measurements of streams, surveys, examinations or other valuable information that may come into his possession concerning any of the duties of his

office, and shall furnish reasonable information in regard to such measurements or surveys to the newspapers of the State upon proper request.

SEC. 6. Any person, association or corporation who shall desire to construct any dam or dyke more than ten feet in height, for the purpose of storing, appropriating or diverting any of the waters of this State, except as otherwise in this act provided, shall submit duplicate plans, drawings and specifications of the proposed work to the State Engineer, who shall as speedily as possible and within fifteen days, examine such plans, drawings and specifications, and, if he approve them, he shall affix his approval thereto, and return one copy of each such plan, drawing or specification, with his approval, to the party or parties proposing to construct the works. If the State Engineer shall disapprove of such plans, drawings or specifications, he shall return the same with his written objections thereto and suggestions of changes to the party or parties filing the same; Provided, Where said dam or dyke is, in the opinion of said engineer, not of sufficient importance to have the provisions of this section apply, then said engineer shall have power, upon written application, to suspend the provisions of this section in regard to such dam or dyke.

SEC. 7. In cases of great importance, especially where life or property would be endangered by the failure of such works, the State Engineer may require excavations to be made to determine the character of the foundation, and require a statement of the facts in the case to be filed in his office before approving such plans, drawings or specifications, or he may, if he deems the public interest demands, visit the locality of such proposed works before the approval of said plans, drawings or specifications, and supervise the construction of the same; and no rights of any kind under the laws of this State shall be deemed to be obtained where the proposed works, as in this section provided, have not been approved by the State Engineer.

SEC. 8. Whenever any party or parties feel themselves aggrieved by the determination of the State Engineer in refusing to approve any plan or specification, as mentioned in the preceding section, then such party or parties may have an appeal to the courts.

SEC. 9. The State Engineer shall inspect, or cause to be inspected, as often as he thinks advisable, every dam or embankment used for holding water in this State, where the same is more than ten feet in height; and if, after any such inspection, such dam or embankment, in the opinion of the State Engineer, is unsafe, and life or property likely to be endangered by reason thereof, he shall order the owner or owners to repair the same, so as to make it safe. If such owner or owners shall neglect or refuse to repair the same within three days after notice to that effect has been given in writing by the State Engineer, then said State Engineer shall report the facts in the case to the Judge of the District Court of the district in which such dam or embankment is situated, who shall, after hearing such facts, if he deem it necessary for the public welfare, order the Sheriff of the county to draw off such water from behind such dam or embankment, and to keep said water drawn off until such time as the orders of the State Engineer shall have been complied with.

SEC. 10. If any person or persons shall report in writing to the State Engineer that any dam or embankment used for holding water is unsafe and dangerous to life or property, then it shall be the duty of said State Engineer to inspect, or cause to be inspected, such dam or embankment as soon as practicable, and, if he considers it unsafe, he shall proceed as provided in Section 9 of this act.

SEC. 11. The State Engineer shall, free of charge, give any information desired by any person as to the proper method of measuring water, or of constructing an apparatus for such measurement.

SEC. 12. The State Engineer may require, and shall receive from the Attorney-General of the State, legal advice upon any question of public interest arising in the performance of his duties under this act, which advice shall be in writing when so desired by said engineer.

SEC. 13. The State Engineer shall make and render to the Governor bi-annually, or oftener if required, a full and true report of the work performed by virtue of his office, which report shall contain any recommendations he may have to make regarding legislation, affecting his office, or

the irrigation laws of the State, or other matters of public interest which his experience and information may suggest.

Sec. 14. In addition to the duties prescribed in the previous sections of this act, the State Engineer shall perform such professional duties as may be required of him by the Governor, and he shall give advice on any matter of a professional nature when called upon by the Governor so to do.

Sec. 15. The Arid Land Commission shall have authority to call upon the State Engineer for such advice and professional services as they may require in the performance of their duties, and the State Engineer shall perform such services without further compensation than the salary herein provided.

Sec. 16. All acts and parts of acts in conflict herewith are hereby repealed.

Sec. 17. This act shall be in full force and effect from and after its passage and approval.

The Secretary reported no unfinished business.

Under the head of new business the Secretary read a communication from R. H. Chapman in regard to taking steps toward establishing a Department of Mines and Mining in connection with the United States Geological Survey.

Mr. Wilson.—I move that it is the sense of the Society that this addition to the Geological Survey is a very desirable one for the mining interests of Montana, and that our Senators and Representatives in Congress be advised of such resolution, and urged to give their support to the measure; and that it be drawn up in like form with the resolution presented by Mr. Chapman.

It was moved by Mr. Booth that the Society request the President and Secretary to write to each of the Representatives of this State in Congress, asking them to use their endeavors to have this bill passed. Seconded by Mr. Wilson and carried.

No further business being presented, the meeting adjourned.

On January 13 the members visited Canyon Ferry Dam (see "Canyon Ferry Dam," Vol. XX, 1898, page 331, May number of Journal of the Association of Engineering Societies). Superintendent M. H. Gerry took especial pains to show the visitors around and explain the construction and works. The change being made in the apron of the dam was of particular interest, the present being an inclined apron. As originally designed and constructed, the spillway portion of the dam was a series of steps, and proper allowance was not made for high water upon the spillway. The width of these steps not being sufficient, a defect which came very near causing the destruction of the dam when the first high water came, the water struck at the extreme outer edge of the first step, and from there had a clear drop to the outer edge of the lower step, the force being sufficient to wash out the lower step in a short time, and to soon make a large excavation, the dam settling and springing out of line from 4 to 5 feet.

At 8.30 p.m. the members and invited guests, consisting of members of the Legislature and many citizens of Helena, gathered at an entertainment in the Chamber of Commerce rooms. The entertainment was enlivened by music by the Helena Military Band, and singing with piano accompaniment. President Page was escorted to the chair and a number of short speeches were delivered. Among the speakers were Hon. E. D. Weed, Speaker Stiff, of the House of Representatives; Messrs. E. H. Wilson, C. W. Goodale and Donald Bradford, of the Arid Land Commission; Judge Stevens, of Missoula, and Messrs. Bruffy and More.

On January 14 the members visited the Peck Concentrator, three miles from Helena. Superintendent F. W. Rossberg escorted the members through the works and explained their operations. The Peck Concentrator is original in design, and entirely dissimilar, in its methods of operation, from all other concentrators.

Returning to Helena, the regular annual meeting was called to order at 3 P.M. by President James M. Page. The minutes of the preceding meeting were read, applications for membership from Carlisle Mason, William H. Harrison, Charles D. Vail, Charles H. Repath and John D. McLeod were presented and favorably considered, and the Secretary was directed to send out the usual letter ballots.

Messrs. Finlay McRae and Wm. H. Williams were appointed tellers to canvass the ballots for officers. The officers elected were:

Eugene Carroll, President; Maurice S. Parker, First Vice-President; Frank L. Sizer, Second Vice-President; Albert S. Hovey, Secretary and Librarian; Forrest J. Smith, Treasurer; James S. Keerl, member of Board of Managers of the Association of Engineering Societies; Finlay McRae, Trustee for three years.

Upon the announcement of the result of the ballot President Page said: "Members of the Society, by your ballots you have elected Mr. Carroll the President of this Society for the coming year. I will appoint Mr. Blackford and Mr. Bickel to escort the President-elect to the chair. Mr. Carroll, it is with much pleasure that I congratulate you upon your election to the office of President of this Society. Gentlemen, I present to you your President for the ensuing year, and in retiring I beg again to thank you for the honors you have conferred upon me during the past year."

Upon taking the chair Mr. Carroll said: "Gentlemen of the Montana Society of Engineers, by your votes you have given me one of the most honorable positions which it is in your power as members of this Society to bestow upon any member, and I assure you that I appreciate the honor. I have always taken a great interest in societies of this character. As soon as I had left school and started in my profession, I joined the American Society of Civil Engineers as junior, and I have stepped up from junior until now I am a full member.

"I am a charter member of the Cincinnati Club of Engineers and of the Cincinnati Association of the American Society, and after I became associated with you engineers in Montana and made my home here, I immediately applied and was elected a member of this Society. When I joined the Society it had a small membership, but an enthusiastic one. At the present time the membership of the Society is such that we are established as a power in the State, and of great benefit to our members. There are still further chances for the Montana Society, and I hope within the next few years to see the membership more than doubled. There are several ways in which this can be done, but no better way than for each individual member of the Society to make himself a soliciting committee to bring in the engineers of the State. At present, most of the older engineers are members of this Society, but there are many young men scattered over the State who, with a little solicitation, would join, and if we should make it attractive to them our membership would vastly increase in very short order.

"One method which has presented itself to me, and which I have dis-

cussed with several members of the Society during the past year, is the holding of the monthly meetings at different parts of the State. For instance, in the Society five or six years ago, the majority of the members were from Helena. At the present time the majority are from Butte, and in Butte we have a very large field of young men and they should be induced to come into the Society. The benefits derived by the younger members of the profession from association in a Society of this class need hardly be enumerated. Under the present system the monthly meetings are all held in Helena, which is a long distance from many members in other parts of the State, so that the young men have not the time and cannot always afford to attend them. I should like to see more papers presented to the Society for discussion through the year. In the past, papers have been put off until the annual meeting, and there is so much business of importance to be transacted at that meeting that the papers fail to receive proper consideration and discussion. It would be much better if the papers were presented at the monthly meetings, and, say, every other meeting in Butte.

"In our Society in Cincinnati we had a hard time to start. We had only a very slim attendance at the meetings for a long while. Finally some practical member proposed that a lunch be provided at the meetings. It immediately increased the membership and made it a social gathering. I believe if we can hold these monthly meetings in a place where we have a large membership, we can introduce some such feature as that.

"Another device for increasing the interest in the Society was called the 'Question Box.' Any member could send to the Secretary a question or a number of questions, which were put in the question box, and once or twice a month the question box was opened. This brought up a great variety of subjects, which were discussed among the engineers at the meeting. I am pleased to say that the Cincinnati Society has joined the Association of Engineering Societies, and is in good condition as to finance and as to membership also.

"I again thank you for the honor conferred upon me, and I hope that each and every one will co-operate with me to make 1899 the banner year for the Montana Society of Engineers."

First Vice-President Maurice S. Parker was not present to take his chair.

Second Vice-President Frank L. Sizer, upon being introduced, spoke as follows:

"Gentlemen, I want to indorse Mr. Carroll's suggestion about distributing these monthly meetings. I thank you, gentlemen, for the honor conferred in my election."

The Secretary, being called upon for a speech, replied:

"Gentlemen, I believe a speech is never expected from the Secretary, so please excuse me. But I wish to thank you for this and previous honors."

Forrest J. Smith, Treasurer, spoke as follows:

"President and Members, all I can say is that I was Secretary long enough to become pretty well acquainted with most of the members, and I thank you for this honor."

Finlay McRae, upon being introduced, responded as follows:

"Mr. President and Members of the Society, I do not know whether to thank you or not for putting me back in harness, but I will try, to the

best of my ability, to fulfill the duties of a Trustee of this Society in conjunction with my two colleagues. I thank you for the honor."

REPORTS OF STANDING AND SPECIAL COMMITTEES.

Mr. Wilson.—The cost of this meeting will be in the neighborhood of $200. I will leave it to the Society to arrange the means by which that expense will be promptly met.

Upon suggestion of the President, Mr. Carroll, Mr. Wilson moved that the members of the Society present be requested to pay $3.50 each for the expenses incurred. Motion carried.

Under the head of new business, Mr. McRae moved that the President appoint a committee of three to look into the matter of changing the headquarters of the Society, and to report upon same at the next monthly meeting on February 11. Motion carried.

The President appointed the following committee: Mr. Wilson, of Butte; Mr. Hovey, of Helena; Mr. Goodale, of Great Falls.

Mr. Goodale offered the following resolutions:

Resolved, That the thanks of this Society are due to the following persons for courtesies extended to the Society at this annual meeting, and that the Secretary be instructed to notify these persons of the appreciation of the Society: To the Committee of Arrangements, to Mayor Edwards, of the city of Helena; to N. G. Miller, Chief Engineer of the Great Northern Railway; to Mr. Kendrick, Vice-President of the Northern Pacific Railway; to Mr. P. J. Tuohy, to Superintendents M. H. Gerry and Whittley, to Mr. S. T. Hauser, to Messrs. Parker, Williams, Page and Carroll for papers which we will hear later on, to Mr. N. Kessler for his kind invitation extended to the Society to visit the tile and sewer pipe works, which, however, the Society was unable to visit.

Motion carried.

President James M. Page then delivered his retiring address, after which Prof. Wm. H. Williams delivered the following address:

ENGINEERING WORK AT THE MONTANA STATE COLLEGE.

Probably few persons in Montana realize what is being done for engineering education in the various State educational institutions. Take as an example the State Technical School,—the Montana State College. This institution now offers four-year courses in mechanical and electrical engineering, which will be found by comparison to be practically equivalent to similar courses offered in Eastern universities; and, what is more, it has the equipment with which to make these courses mean something.

Modern educational methods demand laboratories for instruction and research, and, thanks to the generosity of the Federal Government, this college has been well provided with funds for the purchase of such equipment, and now has well-equipped chemical, physical, biological and engineering laboratories and shops. In every department of instruction theory and practice go hand in hand. The student listens to lectures in physics, chemistry, biology or engineering in the morning, and in the afternoon goes into the respective laboratories for practical instruction along the lines of the previous theoretical work. I venture to say that these laboratories are fully equal in quality and character of apparatus to similar ones provided for undergraduate work in any Eastern universities. The engineering laboratory and shops, for example, now represent an expenditure, exclusive of buildings, of $16,000.

A brief outline of the engineering equipment and practical work may be interesting. In addition to the mathematics, chemistry, language and history of the freshman year, eight hours per week are spent in shop practice in woodwork,—the first half of the year on carpentry, for which provision has been made for twenty-six students, each one having his own set of tools, for which he can be held responsible. The last half of the year is devoted to wood turning and pattern making, in which sixteen students can be accommodated. The shop practice for the first half of the sophomore year is forge work. The forge shop is equipped with ten down draft forges, and all necessary tools for each, including power blower and exhauster; and at the present time these are all in use three afternoons per week. The last half of this year's shop practice is devoted to chipping and filing and lathe work. The junior year shop practice is devoted to drill, lathe, planer and milling machine work, including work in cast iron, wrought iron, gear cutting, etc. The senior year's work is in the construction of some complete machine called the "Senior Model."

The equipment for machine work consists of five lathes, a planer, a milling machine, a shaper, three drills, a tool grinder, a small universal grinding machine and shop saw. The shop building is lighted with electricity from a small dynamo driven from the head shaft, and has in it also an office, tool room, toilet and locker room and boiler room.

Turning now to the engineering laboratory, the juniors and seniors have, for work in steam engineering, an eighty-five horse power boiler with a full outfit of scales, tanks gauges, calorimeters, draft gauges, etc., for boiler trials; four steam engines, one of fifteen, one of forty, and one of sixty horse power, and a threshing engine, three indicator sets, speed counters, tachometers, gauges, calorimeters and brakes for engine trials. The forty horse power engine is especially designed for experimental work, and can be used with a live or exhaust steam jacket, or unjacketed.

For work on the strength of materials there is a Riehlé automatic and autographic testing machine of 100,000 pounds capacity, and an Olson torsion testing machine having a capacity of 50,000 inch pounds, and taking a specimen as large as 1½ inches by 5 feet.

The Riehlé machine is a very fine one, and is the only one of that size owned by any educational institution west of the Mississippi. This machine will take steel specimens up to 1 inch in diameter, and traces its own stress-strain diagram.

The electrical equipment is only about half completed at present, and now consists of a 6 K-W bipolar dynamo, two specially designed multipolar dynamos of 15 K-W each, so arranged as to give direct, or one, two or three phase alternating currents; an arc lighting dynamo and outfit of typical arc lamps, besides a goodly number of ammeters, volt-meters and watt-meters.

This equipment will be liberally increased this year. For the more refined electrical measurements the physical laboratory has a good equipment of electrical test instruments.

This brief outline will show how well the institution is equipped for thorough work along engineering lines. A course in chemistry is also offered, and here, too, the equipment is all that can be desired.

A course in mining engineering is not offered, because the state has made provision for the separate college of mining engineering, but any student can, by taking a combination of the mechanical engineering and

chemical courses, get a mining engineering course that is very nearly equal to the straight mining engineering courses offered in other institutions.

The meeting then adjourned until 8 P.M.

Meeting called to order at 8 P.M.; President Carroll in the chair. Mr. Bradford brought up the subject of pumps and irrigation. It was generally agreed that the centrifugal pump was the best for irrigation, but that pumping water for irrigating farms was a losing business, although it perhaps would pay for gardening.

In reply to a question with regard to keeping canals open in winter, Mr. Carroll stated that his experience had been that when the first heavy frost comes before the first heavy snow, the top of the stream freezes over, leaving a passage which carriers water quite a long time, and that the canal can be kept running all winter. Other members stated that the Dillon, Bozeman and Livingston canals were running during the winter.

The subject of slush ice was brought up.

Mr. Goodale, referring to the Great Falls dam, stated that sometimes they had to stop and dig the ice out.

MR. BRADFORD.—I have been told they made mats of brush, which catch the slush ice and freeze it, so that the water passes underneath.

MR. CARROLL.—I believe that in this climate a covered canal can be run successfully. I would cover it with a regular floor. They never have had any trouble with Daly's flume to the smelters. When we were building our present dam and storage reservoir, we had to deliver water to the city at the same time, and I built a small temporary dam above the main structure, and took the water right out in a flume. All I had was a grating to keep floating ice from getting into the flume. By placing the penstock below the surface, trouble with ice is avoided.

MR. BRADFORD.—How do you account for ice forming on the bottom?

MR. KINNEY.—The same thing happens in the reservoirs where they are shallow. The anchor ice will stick to the bottom.

MR. GOODALE.—The broken or slush ice passes through the larger wheels. To obviate difficulty at Great Falls, we have a canal which we keep open in cold weather, and which carries the ice down under the ice formed in the river above. Being thus conducted, the ice rises to the surface and is carried over the falls.

MR. CARROLL.—From my observations there is no trouble with slush ice within five feet of the surface.

MR. BRADFORD.—When the ice rots does it sink?

MR. CARROLL.—It sinks below the surface, but does not go to the bottom.

MR. BOOTH.—A gentleman in charge at Canyon Ferry said all their ice stopped at the head of the canyon, and they were not bothered with it down at the power house.

MR. BICKEL.—I think if the head of the canal is built properly there is no occasion for the ice to stop there. Generally the dam comes out almost parallel with the river, instead of coming out at right angles. The current going by causes an eddy there, and the ice turns right into the canal as a rule.

MR. CARROLL.—I think it would be well to build a good, heavy screen, so that the ice, coming down in the river, would be shot away from the canal. In a small ditch a heavy iron screen could be made to keep out

the small particles of floating ice or driftwood. I hardly think small water-growth or *débris* would stop it up.

Mr. Bradford.—In the Dearborn canal I put in a very heavy wire fish-screen to keep the fish from getting through, and we had to take it off frequently.

Mr. Carroll.—The water may be clear as crystal, and yet on the screens a vegetable matter gathers that smells "fishy."

Mr. Sizer.—In ordinary cool weather perhaps, say in the earlier part of the winter, there is a very noticeable and disagreeable brackish taste.

Mr. Carroll.—The water in the reservoirs purifies itself. Cleaning the bottom of reservoirs has been tried. They have spent in Boston much money in endeavoring to solve the problem, and I think something like seven per cent. of the cost of the reservoir is spent in cleaning the bottom. We cleaned our reservoir very carefully, but it spoiled this year.

Mr. Bradford brought up the subject of arched steel dams.

Mr. Carroll.—In California they are building an irrigation dam in which the core wall is made with a steel sheeting surrounded by concrete. These steel plates are riveted and calked and then 6 inches of concrete is placed on each side. The concrete is not for strength, but to make it water-tight. I think it is a rock-filled dam. Settlement might produce cracks in the concrete, but not in the plate. The proposition of building dams out in this country is a very serious one, from the fact that our material and labor are so costly that masonry dams are almost barred. I have been quite interested in watching the development of these steel dams, which, by the way, Mr. Bradford can tell you something about.

Mr. Bradford.—Some six or seven years ago I conceived the idea of building arched steel dams, and I submitted the idea to a representative of Cooper, Hewitt & Co., who said he never heard of it before, but that he thought it was perfectly feasible. The arches were to be built convex up-stream, and to be faced with timbers. He submitted the idea to the Engineering Society of Chicago, and wrote me that they all said it was perfectly feasible. Afterwards he told that in California a 100-foot dam so built cost only a hundred thousand dollars.

Mr. Page then gave an interesting description of the construction of the Lima dam, its shortcomings, etc., and Mr. Wilson also described the failure of the drainage canal of the Bimetallic Company. Both failures were due to poor engineering, and resulted in the loss of property. In regard to the Lima dam, Mr. Page stated that if the tunnel, in connection with the dam, had been properly lined, and an adequate spillway provided, no failure would have occurred. In the case of the Bimetallic, the failure was due to amateur engineering, the regular engineer having been discharged, and no doubt this finally resulted in the failure of the Bimetallic Company.

Mr. Goodale moved that 250 copies of the proceedings of the twelfth annual meeting be published. Carried.

Mr. Hovey.—We have one patriot in our Society, Mr. Ripley, who is now serving his country at Manila. The pay of the army is not very large, and I think Mr. Ripley should not be assessed for dues for this year.

Mr. Sizer.—I move that Mr. T. M. Ripley's dues be remitted for the current year of 1899, and that the Secretary be ordered to notify him that this action has been taken. Motion carried.

No further business appearing, the meeting then adjourned.

A. S. Hovey, *Secretary*.

A special meeting was held in the art room of the Butte Public Library, Butte, Montana, on March 11, 1899.

Meeting called to order by President Eugene Carroll at 8.30 p.m., Mr. James S. B. Hollinshead acting as Secretary *pro tem.*

Twenty members and three visitors were present. The minutes of the preceding meeting in Helena were read and approved. The applicants for membership were Lewis C. Parker, of Garnet, Mont., and C. V. Page, of Butte, Mont. Messrs. Winfield J. Flood and Wm. Zaschke, both of Butte, were elected members. An amendment to Article V of the by-laws was introduced, to be acted upon at the next meeting. The Secretary was instructed to have a "List of Members" of the Society printed.

A letter from J. C. Trautwine, Jr., Secretary of Association of Engineering Societies, in regard to allowing Societies ninety per cent. on advertising secured by them for the Journal, was read. A letter from Mr. John F. Davies, Librarian of the Butte Public Library, was read, in which the Trustees of said Library presented to the Society the use of the art room for meetings, and shelf room for Society's library. A vote of thanks was extended to the Trustees of the Library for this courtesy; also to Mr. E. H. Wilson for his energetic endeavors, in the Sixth Legislative Assembly, to pass the bills providing for the measurement of water, and the establishment of the office of State Engineer. The Society was much encouraged by the passage of the following bill:

HOUSE BILL No. 29.

Introduced by E. H. Wilson.

A BILL FOR

An Act Establishing a Standard of Measurement for Water, Defining the Equivalent of a Miner's Inch, and Repealing Section 1893, Title VIII, Part IV, Division II, of the Civil Code of the State of Montana, and all Conflicting Laws.

Be it enacted by the Legislative Assembly of the State of Montana:

Section 1. Hereafter a cubic foot of water (7.48 gallons) per second of time shall be the legal standard for the measurement of water in this State.

Sec. 2. Where water rights expressed in miners' inches have been granted, one hundred miners' inches shall be considered equivalent to a flow of two and one-half cubic feet (18.7 gallons) per second; two hundred miners' inches shall be considered equivalent to a flow of five cubic feet (37.4 gallons) per second, and this proportion shall be observed in determining the equivalent flow represented by any number of miners' inches.

Sec. 3. Provided, that the provisions of this bill shall not affect or change the measurement of water heretofore decreed by a court, but such decreed waters shall be measured according to the law in force at the time such decree was made and entered.

Sec. 4. Section 1893, Title VIII, Part IV, Division II, of the Civil Code of the State of Montana, and any laws in conflict with this act, are hereby repealed.

Approved March 3, 1899.

Robert B. Smith, *Governor.*

Prof. A. M. Ryon, by numerous experiments at the State Experiment Station, determined the equivalent of a miner's inch, given in the above bill. (See Measurement of Water, Journal of the Associaton of Engineering Societies, Vol. XIV, January, 1895.)

Mr. F. W. Blackburn, ex-City Engineer of Butte, read a paper on "Development of Roads and Street Pavements," followed by a paper from

Clar. W. Swearingen, City Engineer of Great Falls, relative to "Experience in Paving in Great Falls." In the discussion which followed, the members generally agreed with Mr. Blackford that properly constructed wooden blocks and asphalt pavings were the best under the most trying conditions. A vote of thanks was tendered for the interesting papers, whereupon the meeting adjourned.

A. S. Hovey, *Secretary*.

Engineers' Club of Cincinnati.

Cincinnati, Ohio, February 16, 1899.—103d regular meeting. Beginning with this meeting the new arrangement of assembling for dinner at an early hour was inaugurated.

Twenty-three members and visitors were present for dinner, which was served at 6.10 p.m.

The meeting for regular order of business was called to order at 7.10 p.m. with President Hazard in the chair.

There were twenty-two members and six visitors present.

Minutes of the meeting of January 19 were read and approved.

Applications for active membership were received from Mr. Allan Cox and Mr. Alfred Frank.

On ballot being taken Mr. Hadley Baldwin was elected to active membership.

Mr. G. B. Nicholson, for the Committee on Memoirs, presented a short sketch of the life of Israel Ludlow, the pioneer surveyor of Ohio, who in 1789 surveyed the original town plot of Cincinnati, and those of Hamilton and Dayton a few years later, besides other work for the United States Government in this vicinity. This was ordered received and entered on the records of the Club.

The President advised the Club that the matter of joining the Association of Engineering Societies had been consummated.

Mr. M. D. Burke read the paper for the evening, on "Street Railway Track Construction." The paper was quite fully discussed by Messrs. Read, Punshon, Stanley, Innes, Rabbe, Hazard, Wulff, Elzner, Meeds and Burke.

Adjourned.

J. F. Wilson, *Secretary*.

104th Regular Meeting, Cincinnati, O., March 16, 1899.—Dinner was served at 6.15 p.m.

Regular meeting called to order at 7.20 p.m.; President Hazard in the chair and twenty members present.

Minutes of the meeting of February 16 were read and approved.

Applications for active membership were received from Messrs. L. A. Rose, Supervisor of Track C., C., C. and St. L. Ry., Cincinnati Div.; C. L. Parmelee, Chief Engineer Continental Filter Company, New York city; Wm. E. Gunn, Asst. Engr. on reconstruction of Covington and Cincinnati suspension bridge, and Chas. A. Knowlton and John A. Hiller, Asst. Engrs. on construction of new water works for Cincinnati at California, O.

Messrs. Allan Cox and Alfred Frank were elected to active membership.

The Secretary announced the death of Fred. C. Weir, President of the Weir Frog Company. Mr. G. B. Nicholson was appointed a committee to prepare a suitable memoir of Mr. Weir.

The paper for the evening was read by Mr. James M. Harper, on "The Liberty Street Tunnel and Sewer." The part of the sewer referred to in the paper was constructed in 1868-9, and was composed of four rings of hard-burned hand-made sewer brick, the inside diameter being 9 feet 6 inches. Louisville cement was used.

In 1878, eight years after the sewer was put in service, the bottom was found to be in very bad condition. For a lateral distance of 2 or 3 feet in the invert the bricks had been abraded to such an extent that the first course and a considerable part of the second course were entirely gone, the third course even showing wear in places.

Repairs were made by putting in limestone blocks about 4 feet long, 12 inches wide and 8 inches thick. These were dressed on all sides except the bottom, and were laid in pairs with joint in the center line of the sewer. Later this construction was changed and single blocks were laid 20 inches to 24 inches wide and only 4 inches thick.

In 1898 an examination showed that the 4-inch blocks were almost entirely worn out, holes being worn in places through the stones and about 4 inches worn from the 8-inch stones, and the joints between them worn in a "V" shape nearly to the bottom. Repairs are now being made by filling these joints with a quick-setting cement and replacing the 4-inch blocks with vitrified brick.

Specimens of the old stone and brick from the tunnel were exhibited, showing the peculiar manner in which they had been worn away.

Adjourned.

J. F. Wilson, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., February 15, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8.10 o'clock P.M.; Vice-President C. Frank Allen in the chair. Sixty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Leonard H. Davis, Guy C. Emerson, Robert R. Evans and James Rice were elected to membership.

The chair announced that the President had appointed Messrs. Chas. H. Swan and Edmund S. Davis as the tellers to canvass the ballots for officers at the annual meeting on March 15.

The Secretary read a communication from the Austrian Society of Engineers and Architects, inviting this Society to be present at the exercises to be held at Vienna on March 18, commemorative of the 50th anniversary of the organization of that Society. On motion, the letter was referred to the President for a suitable acknowledgment, on behalf of the Society.

The literary exercises consisted of a talk by Mr. George S. Rice on "Grouting of Defective Work on the New Croton Aqueduct." Mr. Rice gave a very interesting account of the building of the new aqueduct and of the methods employed to discover the defective portions of the work. He then described very fully the work of grouting above the crown of the arch. The description was illustrated by a large number of lantern views.

Adjourned.

S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

486TH MEETING, MARCH 1, 1899.—Meeting was called to order at 8.20 P.M.; President Colby in the chair. Thirty-one members and six visitors were present. The name of Mr. R. H. Phillips was proposed for membership. The names of Messrs. V. K. Hendricks, F. F. Axtell, H. B. Shaw and W. A. Bennett, having been recommended by the Executive Committee, were balloted for and all declared elected members of the Club.

Col. E. J. Spencer then read the paper of the evening, entitled "World's Fairs." The histories of previous expositions, international in their character, were briefly gone over, and mention made of some of their main features. The cost, financial success and attendance of all these were given, and some comparisons made, showing the relative sizes. The growth of electric lighting was traced through the later fairs.

A large number of lantern slides were shown, illustrating the various architectural and engineering features of the Paris, 1889; Columbian, 1893, and Omaha, 1898, Expositions.

Some interesting statistics of the number of people attending the Paris Exposition, and the estimated amount of money which the visitors brought, were read.

A few questions were asked, and Mr. Julius Pitzman made some remarks on the prospective Louisiana Purchase Exposition, giving the reasons for holding it and explaining what special legislation is necessary to successfully accomplish it. He also said that it was highly important to make it entirely different from the Chicago Fair, and suggested that the members try to devise some novel idea for it.

There being no further business, the meeting adjourned to another room, where lunch was served.

E. R. FISH, *Secretary.*

487TH MEETING, MARCH 15, 1899.—The meeting was called to order at 8.20 P.M. by President Colby. Eighteen members and one visitor were present. The minutes of the 486th meeting were read and approved. The minutes of the 271st meeting of the Executive Committee were read. The name of Mr. Hiram Phillips was proposed for membership, and the name of Mr. R. H. Phillips, having been recommended by the Executive Committee, was balloted for and declared elected a member of the Club. Plans for the celebration of the 30th anniversary of the Club were discussed. Details of arrangements to be left to the Entertainment Committee.

The paper of the evening, "Recent Concrete Construction on the Illinois and Mississippi Canal," was then read by the Secretary, in the absence of the author, Mr. J. W. Woermann. The paper gave a description of the methods of construction of the locks being constructed on the canal, and the proportions and character of the materials used. Costs of the various items making up the total cost of two of the locks were given and comparisons made of their cost per cubic yard on this work with the cost of similar work in other parts of the country. Some drawings and photographs showing the details of construction were exhibited. The discussion was participated in by Messrs. Ferguson, Dean, Colby, McMath and Ockerson. There being no further business, the Club adjourned to another room, where lunch was served.

E. R. FISH, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, March 3, 1899.—Called to order at 8.30 p.m. by President Percy.

The minutes of the last regular meeting were read and approved. The following were elected by ballot: Members—E. M. Fraser, mechanical engineer; A. Ballantyne, engineer, U. S. Light House Department; F. C. Herrmann, civil engineer. Associates—Thomas W. Butcher, builder; Daniel McPhee, builder; Frank H. Masow, builder; John D. McGilvray, builder; Chas. A. Day, builder.

The following applications were made and referred to the Board of Directors: For members—Geo. N. Randle, assistant engineer, Board of Public Works, Sacramento, Cal., proposed by C. E. Grunsky, D. E. Hughes and Otto von Geldern; W. C. Elsemore, City Engineer of Eureka, Cal., proposed by D. E. Hughes, C. D. Marx and Otto von Geldern; Walter de Buxton, assistant engineer, S. Fe, P. R. R. Co., Williams, Arizona, proposed by Louis Falkenau, G. W. Percy and Otto von Geldern; H. A. Brigham, mining engineer, of San Francisco, proposed by C. E. Grunsky, H. C. Behr and Otto von Geldern. For associates—F. E. Knowles, builder, San Francisco, proposed by G. W. Percy, Hermann Barth and E. T. Schild; J. W. Miller, builder, San Francisco, proposed by G. W. Percy, Hermann Barth and Thos. W. Brooks.

The President referred to the Society's proposed visit to the battleship "Iowa," and, upon discussing the subject, the Secretary was instructed to circulate notices to members, stating the details of the intended trip, and asking all who desire to paruicipate to inform the Society.

The Secretary was made a committee of one to perfect the necessary arrangements for the visit to the ship.

President Percy read a paper, entitled "Mechanical Influences in Architecture," which was discussed by a number of members present.

Adjourned.

Otto von Geldern, *Secretary*.

Detroit Engineering Society.

The 38th regular meeting of the Society was held in the smaller lecture room of the Detroit Art Museum, Friday, March 24, 1899. President Geo. Y. Wisner presided. There were about one hundred and ten members and guests, including many ladies, present.

The paper of the evening, "Locks and Lock-gates for Ship Canals," was read by the author, Mr. Henry Goldmark. It was illustrated by eighteen lantern slides made mainly from photographs of the locks at Sault Ste. Marie, Mich.

Adjourned.

A special meeting of the Society was held at the Hotel St. Claire, Friday, April 7, 1899. First Vice-President W. J. Keep presided. Mr. W. C. King was elected to resident membership. The evening was devoted to a discussion on "Locks and Lock-gates for Ship Canals." It was opened by Mr. Henry Goldmark and participated in by Messrs. Woodard, Dunlap, Himes, Pope, E. Molitor, D. Molitor and Russel.

Adjourned.

Henry Goldmark, *Secretary*.

Association of Engineering Societies.

Vol. XXII. **APRIL, 1899.** No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

Annual Meeting, March 15, 1899.—The annual meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, Boston, at 7.45 o'clock p.m.; Vice-president C. Frank Allen in the chair. Eighty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Walter A. Gleason, Channing Howard, Harry F. Macomber and Robert W. Pratt, Jr., were elected members of the Society.

The death of Charles E. C. Breck, a member of the Society, was announced, and, on motion, the President was requested to appoint a committee to prepare a memoir.

The thanks of the Society were voted to Mr. Herbert Tate, President of the City Refuse Utilization Company, for courtesies shown the members who took part in the excursion this afternoon.

The annual report of the Board of Government was read by the chairman, and by vote it was accepted.

The Secretary and the Treasurer each presented his annual report, and by vote they were accepted.

The report of the Committee on Excursions was presented by Mr. Metcalf, and by vote it was accepted.

The Librarian presented the report of the Committee on the Library, and by vote it was accepted.

Mr. FitzGerald, for the Committee on Quarters, submitted a brief report, which was accepted.

On motion of Mr. Stearns, it was voted that the question of continuing the several special committees of the Society, and the selection of the members thereof, and the question of printing the various reports which have been received this evening, be referred to the Board of Government with full powers.

On motion of Mr. FitzGerald, it was voted that the Board of Government be authorized to take any action necessary in the matter of renewing the leases or making a new lease with the Tremont Temple Baptist Church, with the New England Water Works Association and with the Hersey Manufacturing Company, or other desirable leases, and that the President and Treasurer be authorized to sign such leases on behalf of the Society.

On motion of Mr. Fales, the Board of Government was authorized to expend a sum not exceeding $50 for standard engineering books for the Society's library.

Mr. Otis F. Clapp then gave a very interesting and entertaining account of the construction of the sewage pumping station and the precipitation tanks at Providence, R. I. The description was very clearly illustrated by lantern slides.

Messrs. Chas. H. Swan and Edmund S. Davis, the tellers of the election, submitted the result of the letter ballot for officers. There being no election for President, Vice-President and Director by letter ballot, the meeting proceeded to choose from the two candidates for each office having the highest number of letter ballots.

The President announced, as the result of the balloting, the election of the following officers:

President—C. Frank Allen.

Vice-President (for two years)—T. Howard Barnes.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Frank L. Fales.

Director (for two years)—Alfred E. Burton.

Adjourned.

S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1898-99.

Boston, Mass., March 15, 1899.

To the Members of the Boston Society of Civil Engineers:

In compliance with the provisions of the Constitution, the Board of Government submits its report for the year ending March 15, 1899.

At the annual meeting a year ago the total membership of the Society was 461, of which 453 were members, 5 honorary members and 3 associates.

During the past year we have lost 17 members. 2 by death, 6 by resignation and 9 by forfeiture of membership for non-payment of dues.

There have been added to the Society during the year 40 members; 38 of these have been elected, 1 of whom was transferred from the Engineers' Club of St. Louis, and 2 former members have been reinstated. Our present membership consists of 5 honorary members, 5 associates and 474 members; a total of 484.

The record of deaths during the year is as follows:

James Francis, died December 1, 1898.

Charles E. C. Breck, died January 29, 1899.

Ten regular and two special meetings have been held during the year. The special meeting held on November 11 was devoted to exercises commemorative of the fiftieth anniversary of the organization of the Society. The seventeenth annual dinner of the Society was given at the Hotel Brunswick on February 7, 1899.

The average attendance at the meetings (not including the semi-centennial meeting and the annual dinner) was 75, the largest being 110 and the smallest 52. The attendance at the semi-centennial meeting was 170, and at the annual dinner 135.

The following papers have been read at the several meetings:

March 16, 1898.—Address by Past-President W. E. McClintock, "Road Construction." (Illustrated.)

March 30, 1898.—"Some Instances of Piles and Pile Driving, New and Old," by H. J. Howe.

April 20, 1898.—"State, City and Town Boundaries," by H. B. Wood. "Memoir of William C. Hall."

May 18, 1898.—"Co-ordinate Survey of Boston," by F. O. Whitney.

June 15, 1898.—"Modern Steam Plant for Electric Railways," by A. U. Jaastad. "Story of the Street Railway," by Gilbert Hodges.

September 21, 1898.—"Proposed East Boston Tunnel," by H. A. Carson. (Illustrated.)

October 19, 1898.—"Engineering Features of the Spanish War," by I. N. Hollis. (Illustrated.)

November 11, 1898.—Semi-Centennial Celebration. Opening Address, by President H. A. Carson. Historical Address, by Past-President Desmond FitzGerald, and Brief Address, by Samuel Nott.

November 16, 1898.—"The Maintenance of the System of Sewers in Newton, Mass.," by Stephen Childs.

December 21, 1898.—"Power and Equipment of Electric Railways," by Messrs. H. H. Hunt and C. K. Stearns. "Comparative Tests of Different Forms of Cement Briquettes," by Jerome Sondericker.

January 25, 1899.—"Experience in Sewer Construction," by L. M. Hastings. "Memoir of James Francis."

February 15, 1899.—"Grouting of Defective Work in the New Croton Aqueduct," by George S. Rice. (Illustrated.)

The informal meetings held in the Society's library have been continued during the year. The subjects discussed have been as follows:

March 23, 1898.—"Investigations as to the Restoration of Green Harbor, in the Town of Marshfield," by F. W. Hodgdon and X. H. Goodnough.

April 6, 1898, and April 27, 1898.—"A Few Thoughts on Dam Construction," by Reuben Shirreffs.

November 30, 1898.—"Providence Railroad Terminals," by G. B. Francis.

December 7, 1898.—"Longwood Avenue Bridge," by A. H. French.

January 11, 1899.—"An Account of Some of the Changes Made Along the South Shore by the Recent Storm," by F. W. Hodgdon.

February 1, 1899.—"Salt Water Fire System in Boston," by F. A. McInnes.

March 1, 1899.—"Plan and Engineering Work of the Associated Factory Mutual Insurance Companies," by L. H. Kunhardt.

March 8, 1899.—"Abolition of Grade Crossings at Readville, and at Other Points on the N. Y., N. H. and H. R. R.," by G. R. Hardy.

The attendance at these informal meetings has been fully as large as in former years, and in two or three instances as many were present as could be comfortably seated.

In accordance with the recommendation of this board, the Society at the April meeting appropriated $50 for the purchase of standard engineering works. This appropriation has been expended and fifteen books have been added to the library. The board would recommend that the same amount of $50 be appropriated for the purchase of engineering books during the coming year.

The report of the Treasurer shows that the Society has prospered financially during the year. Our permanent fund has increased $829.90, and our current fund is $702.46 larger than it was a year ago.

The lease to the Society of the Society rooms will soon expire, and the leases from the Society to the New England Water Works Association and the Hersey Manufacturing Company will expire before our next regular meeting. It is desirable that authority should be given to the Board of Government to act for the Society in relation to these matters, and that the President and Treasurer of the Society be definitely authorized to sign these leases.

The most important occurrence of the year has been the celebration of the semi-centennial of the founding of this Society. The first formal measures for its formation and the actual organization of the Society appear to have been effected during the spring and summer of 1848. It seemed desirable that the formal celebration of this semi-centennial anniversary should be held in the fall of the year in order to afford the most favorable opportunity for the attendance of the members. The celebration was held at the Hotel Vendome, on November 11, 1898, and the exercises were opened by the reading of letters of congratulation from various engineering societies, a retrospective address by President Carson upon Boston fifty years ago, after which Past-President FitzGerald delivered an address reviewing the history of the Society itself. A short address was made by Mr. Samuel Nott, one of the founders, and for many years Secretary, of the Society, and the remainder of the evening was devoted to social diversion, of which dancing formed an enjoyable part. The proceedings were of great interest throughout, and the occasion was exceptionally pleasant. Ladies were invited and many attended.

The relations between this Society and other engineering societies have been, as usual, pleasant. In particular it has always been true that this Society has always been a stanch supporter of the national society, the American Society of Civil Engineers. The present year is particularly auspicious for harmony of action since the American Society of Civil Engineers has elected for its President one of our Past-Presidents, whose good services to our own Society have been so conspicuous that no microscope is necessary to bring them to our vision, nor could any such instrument magnify the regard for him entertained by our Society.

Respectfully submitted for the Board of Government,

C. Frank Allen, *Vice-President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1898-99.

CURRENT FUND.

Receipts:

Dues from new members	$208.00	
Dues for year 1897-98	5.00	
Dues for year 1898-99	3,176.00	
Dues for year 1899-1900	18.00	
Rent of rooms	800.00	
Sale of Journals	10.50	
Interest on deposits	8.21	
Fines on books	.91	
Balance on hand March 17, 1898	224.53	
		$4,451.15

Expenditures:

Rent	$1,635.00	
Association of Engineering Societies	709.75	
Secretary's salary	400.00	
Printing and postage	344.83	
Periodicals and binding	92.70	
Incidentals	101.72	
Annual dinner	91.50	
Semi-centennial commemoration	10.75	
Books for the library	49.51	
Stereopticon at meetings	41.00	
Reporting meetings	8.00	
Lighting rooms	12.89	
Furniture	26.51	$3,524.16
Balance on hand		$926.99

PERMANENT FUND.

Receipts:

Thirty-seven entrance fees	$370.00	
Shares of Merchants' Co-operative Bank, retired	263.00	
Subscription to Building Fund	50.00	
Interest and dividends	128.13	
Balance on hand March 17, 1898	1,075.49	
		$1,886.62

Expenditures:

Dues on shares Merchants' Co-operative Bank	$312.00	
Dues on shares Workingmen's Co-operative Bank	300.00	
Dues on shares Volunteer Co-operative Bank	300.00	
Deposit in Boston Five-cents Savings Bank	37.08	
Deposit in Provident Institution for Savings	37.53	986.61
Balance on hand		$900.01

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 15, 1899.

One Republican Valley Railroad bond (par value)	$600.00
25 shares Merchants' Co-operative Bank	3,042.80
25 shares Workingmen's Co-operative Bank	1,283.25
25 shares Volunteer Co-operative Bank	1,237.50
Deposited in Boston Five-cents Savings Bank	1,087.88
Deposited in Provident Institution for Savings	1,101.47
Deposited in Old Colony Trust Company	900.01
	$9,252.91
Amount belonging to Permanent Fund March 16, 1898	8,423.01
Increase during the year	$829.90

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$9,252.91
Current Fund	926.99
	$10,179.90
Total amount March 16, 1898	8,647.54
Total increase during the year	$1,532.36

Report of Committee on Excursions.

Boston, Mass., March 15, 1899.

Your Excursion Committee presents the following report:

Twelve excursions have been held during the year, as follows:

On April 20, 1898, to the South Union Station, at Boston, to see the erection of the roof trusses and other structural ironwork; attendance, 50.

On May 18, 1898, to Brookline, Mass., to inspect the Brookline Public Bath House and the stone arch bridges in the parkway; attendance, 20.

On June 15, 1898, to Everett, Mass., to visit the plant of the New England Gas and Coke Company, under construction; attendance, 29.

On July 22, 1898, an excursion down Boston Harbor, through the courtesy of Lieut. Col. S. M. Mansfield, Engineer Corps U, S. A., to witness the explosion of mines off Fort Independence and visit the Government shops at the fort; attendance, 230.

On August 19 and 20, 1898, to Portland, Maine, to visit, by invitation of the company, the works of the Portland Stoneware Company. The party was also given a trolley ride about Portland, a steamboat ride down Casco Bay and a shore dinner and theater party at Peaks Island; attendance, 29.

On September 21, 1898, to Middlesex Falls to see the New Stoneham Reservoir and Gate House at Spot Pond; attendance, 55.

On October 21 and 22, 1898, to Holyoke, Mass., where visits were made to the Riverside Paper Mills, the Deane Steam Pump Works and the new dam of the Holyoke Water Power Company, across the Connecticut River. A trip was also taken to the summit of Mt. Tom; attendance, 19, 13 of whom came from Boston, the remainder joining the party at Holyoke.

On November 16, 1898, to the plant of the Boston Electric Light Company; attendance, 30.

On December 15, 1898, to the South Union Station to inspect the head house and other buildings; attendance, 60.

On January 18, 1899, to the Boston and Oxford Exchanges of the New England Telephone and Telegraph Company; attendance, 40.

On March 1, 1899, to East Everett, Mass., to visit the works of the New England Structural Company; attendance, 18. (This excursion was arranged for the day of the February meeting, but was postponed two weeks on request of Mr. Douglass.)

On March 15, 1899, to the plant of the City Refuse Utilization Company, on Atlantic avenue, Boston; attendance, 20.

It will be seen that the total attendance on these excursions during the year has been 600.

The funds now in the hands of the committee amount to $24.11.

Respectfully submitted,

R. S. Hale,
Henry F. Bryant,
Leonard Metcalf,
H. S. Adams,
Benj. W. Guppy,
Excursion Committee.

REPORT OF THE COMMITTEE ON THE LIBRARY.

BOSTON, MASS., March 15, 1899.

To the Boston Society of Civil Engineers:

GENTLEMEN:—The Committee on the Library presents the following report:

Since the last annual meeting there have been added to the library 489 titles. Of this number 312 are pamphlets and paper-covered reports and 177 are bound volumes. Fifteen volumes were purchased, 56 are periodicals and reports bound by the Society and the remainder were obtained by gift and exchange.

Of the shelf room vacant in 1897, about one-half has now been filled.

We have added a small revolving bookcase, in which it is proposed to keep the new accessions for a limited time before putting them in their proper places on the shelves.

One hundred and forty-six books have been borrowed from the library by members for home use, against 68 borrowed last year. Fines have been incurred for keeping books over time to the amount of $0.54, which has been turned over to the Treasurer.

The work on the subject index of Municipal Reports progresses slowly. About one-half of the reports have been indexed and cards written. In order that the members may have the use of the index, although still incomplete, the cards have been put in the last drawer of the catalogue cabinet, and they will be added to as the work goes on.

Your committee recommends the appropriation of $50 for the purchase of standard engineering books.

Respectfully submitted,

FRANK L. FALES, *Librarian*,
CALEB MILLS SAVILLE,
ANDREW D. FULLER,
FREDERIC H. FAY,
FRANK P. MCKIBBEN.

The Evolution of Engineering.

BY SIDNEY F. LEWIS, PRESIDENT.

[Read before the Louisiana Engineering Society, January 14, 1899.*]

IN complying to-night with the provision of our Constitution which requires of the President to make an annual address, I feel that I can hardly do justice to the honor, and I can scarcely hope that my efforts will prove either attractive or novel to my *confrères* around me.

The field of applied science has of late years become so broad, and the development of its numerous and varied applications so rapid, that in an address of this kind one feels at a loss how and where to begin in the treatment of the subject. We all recognize that with the progress of the age the profession is dividing itself into specialties, and, as the title of our Society indicates, our membership should find abundant opportunities to satisfy their professional ambition by mastering one of its various branches, instead of attempting to acquire proficiency in all. This of itself should be

*Manuscript received March 16, 1899.—Secretary, Ass'n of Eng. Socs.

an incentive to future encouragement in the growth and continued prosperity of our Society. The science of engineering does not owe its heritage to any stage in the world's history. While no one race or era can lay claim to its inception or its birth, every civilization may be said to have aided in its development.

If we trace the history of its beginnings, we find, from the records of early human achievements, that the early builders were guided by the knowledge of the results of experiences handed down from generation to generation, rather than by physical laws as established and considered in our enlightened age. From the beginning the progress of engineering development in every nation has been largely influenced by its political history.

Rulers of small states and principalities had little incentive to construct public works. But, as power became centralized and expansion of territory took place, wealth followed, and the perpetuity of civil power in the state was made dependent upon the extension of internal improvements and development of its resources. Wherever the centers of advanced civilization were located, there we find engineering works of importance.

With the ancient nations, every form of engineering was known which did not require the application of the generated forces. They built canals for transportation and irrigation, reservoirs and aqueducts, docks, harbors and lighthouses. They erected bridges of wood and stone, as well as suspension bridges, laid out roads, cut tunnels, constructed viaducts, planned roofs for their massive buildings, tested the strength of their materials, instituted elaborate systems of drainage, planned fortifications, designed engines of attack, built temples dedicated to their gods and the sun; in fact, covered, to a greater or less degree, all departments of hydraulic, bridge and road, sanitary, military and mechanical engineering, architecture and landscape gardening.

Among the many monuments of ancient engineering we read that the city of Nineveh, which stood on the east bank of the Tigris, was built of enormous dimensions, being fifteen miles in length, nine in breadth and forty-eight in circumference. The houses stood apart, each surrounded by gardens, parks and farms, whose size varied according to the rank and wealth of the respective proprietors. The city was inclosed within one wall as a common defense. This wall was two hundred feet in height, and so wide that three chariots might drive abreast, and upon it were constructed fifteen hundred lofty towers.

The city of Babylon stood in a plain and was perfectly square. The River Euphrates ran through the center of the town, and also supplied water to the ditches, which were excavated in front of the walls. The streets were perfectly straight, and crossed each other at right angles. The city was about fifteen miles in length, and consequently its perimeter was sixty miles. Its houses were built of bricks made of clay, found in its vicinity, sunburnt or burnt in kilns, and cemented with bitumen, with layers of rushes and palm leaves between the strata of brick. The walls of Babylon were three hundred feet high, and eighty-seven feet thick, and pierced by a hundred gates, all made of solid brass. Wide, straight streets, from each of the gates, crossed each other at right angles, which divided the city into six hundred and seventy-six squares, each of two and a quarter miles in perimeter. Some of these squares were used as parks or pleasure

grounds. A bridge passed over the Euphrates between two palaces on the opposite banks, which were also connected by means of a tunnel. The length of the bridge proper was an eighth of a mile, and its width thirty feet, and a long causeway or approach led to the bridge on each side of the river.

The temple of Belus, the supreme deity of the Babylonians, was the most wondrous structure of the city. It was, at its foundation, one-eighth of a mile in length, and about the same in breadth. Its height is said to have exceeded six hundred feet, which is greater than that of the Egyptian Pyramids. It was built in eight stories, gradually diminishing in size as they ascended. Instead of stairs, there was a sloping terrace on the outside, sufficiently wide for carriages to ascend. The temple was adorned with idols of gold. Palaces stood near the temple, and the inclosures and pleasure grounds of one of these palaces covered a space eight miles in circumference. Within its precincts were the celebrated hanging gardens, consisting of terraces one above another, raised upon pillars higher than the walls of the city, well floored with cement and lead, and covered with earth, in which the most beautiful trees and shrubs were planted.

The engineers of ancient Rome were especially noted for their ability to construct durable roads and aqueducts. The great system of military roads was begun by Appius Claudius (B. C. 312), who constructed a paved road to Capua, called from him the Appian way. Others followed after, all issuing from the capital. They bound the different cities and colonies not only together, but to Rome, and were the great highways by which intelligence was speedily carried and the Roman armies marched. In preparing to make a road, two trenches were first dug, parallel to each other, to mark the width. The width was about thirteen feet. The loose earth between these trenches was then removed, and the excavation was continued until a solid foundation was reached. In swampy lands a basis was formed artificially. Above the foundation, small stones were first laid, then a mass of broken stones about nine inches thick, cemented with lime, and above this were fragments of brick and pottery, about nine inches in depth, also cemented. Above this, large polygonal blocks of the hardest stone, fitted and joined with great nicety, were placed. The center of the road was a little elevated, to permit the water to run off. A footpath was constructed on each side. At about the same time (B. C. 313) Appius commenced the system of aqueducts which were to supply the capital with pure water from the Sabine Hills.

No undertakings of the Romans present more striking evidence of their energy, skill and untiring perseverance than the military roads and aqueducts. The latter were constructed at an expense of a vast amount of toil and money. Over hills, valleys and plains, and sometimes in subterranean channels, sometimes on long ranges of lofty arches. These subterranean channels were formed of stone or brick, and were arched in order to keep the water pure. Apertures were made for ventilation. The channel had a gradual slope, and the bottom was coated with cement. When the aqueduct was carried through solid rocks, the rock itself served as a channel. In order that the water should deposit the sedimentary matter which it held in suspension, large receptacles, or ponds, were made at convenient places for it to enter. In the city it was received into a reservoir, and thence conducted, through lead or earthen pipes, into smaller reservoirs in the

different districts which it was to supply. Four of the old Roman aqueducts are still in use. The New River in London, and the Croton aqueducts in New York, are constructed on the plan of the Roman aqueducts. It has been estimated that the total amount of water delivered by these aqueducts is equal to that of a stream twenty feet wide by six feet deep, constantly pouring into Rome at a fall six times as rapid as that of the River Thames, a volume equivalent to over 300,000,000 gallons per day.

They were the most wonderful structures of ancient Rome, and well might excite the admiration expressed by Pliny. "If any one will carefully calculate the quantity of the public supply of water for baths, reservoirs, houses, trenches, gardens and suburban villas, and along the distance which it traverses, the arches built, the mountains perforated, the valleys leveled, he will confess that there never was anything more wonderful in the whole world."

Their public and private baths, amphitheaters, temples and palaces exemplify the type of work constructed during the era of wealth and luxury, when Rome was mistress of the world. The power of the Roman Empire was upheld as much by the knowledge, genius and energy of its engineers as by its generals.

Rome, in her pristine grandeur, had her Coliseum and her Pantheon. Of the Coliseum Lord Byron, in "Childe Harold," apostrophises:

> "While stands the Coliseum, Rome shall stand,
> When falls the Coliseum, Rome shall fall,
> And when Rome falls—the world."

The monuments of Roman engineering followed the paths of the conqueror; for, in every part of the world, from the shores of the Atlantic to the borders of India, from the Baltic to the Desert of Sahara, the engineer of that period has left the remains of his skill and ingenuity.

During the dark ages, from the downfall of the Roman Empire, about the fifth century, until the beginning of the sixteenth, the sciences were almost lost, being practiced only by the monks and other religious castes. Engineering development, since the beginning, has been influenced by the outgrowth of natural surroundings. In Greece, Italy, Switzerland and France the mountains, streams and gorges turned the attention of the engineer toward tunnels and bridges. So, in the lowlands of Holland and Belgium the continental battles against floods developed a race of engineers with special skill in drainage and dyke building, while in England, surrounded on all sides by a stormy sea, thought was directed to lighthouses, harbors and docks.

In the early part of the sixteenth century, our Dutch ancestors began their work of adding to the area of their country by building canals and dykes and reclaiming land. And, as Holland gradually provided herself with her magnificent system of artificial waterways, her industrial energy was rewarded as the people increased in prosperity, and attained a position of power among the nations of Europe, developing among her people traits of character which were inherited by those who were afterwards to found the metropolis of the New Republic. In Italy the reclamation of its marshes and submerged lands took place in the seventeenth century. In Russia, Peter the Great devoted his time and energy to internal improvements, and laid the plans for a system of inland navigation to connect the new city of St. Petersburg with the Caspian Sea.

Under the reign of Louis XIV of France (1638-1715) systematic improvement of the public highways leading to Paris was inaugurated. The Languedoc Canal was built, and the city of Paris was paved and lighted, during his reign. The Academy of Inscriptions in 1663, the Academy of Sciences in 1666, and that of Architecture in 1671, were founded, and the "Commissary General of Fortifications" was created by him. "L'ésole des ponts et Chaussées" was established in 1720, and in its walls have graduated many able and practical engineers. In 1803, Napoleon Bonaparte, during his Consulship, founded the University of France, and, three years later, in 1806, he removed the Military School from Fontainebleau to St. Cyr, and it has furnished France and the world with many distinguished military and civil engineers. Although England produced eminent engineers in the sixteenth and seventeenth centuries, she was dependent, for her engineering, even more than for her pictures and music, upon foreigners. Technical knowledge lay dormant with her people until the steam engine was introduced. At the time when Holland had made great progress in internal improvement, and in her systems of water communication, and when France, Germany, and even Russia had opened up important lines of inland navigation, there was not a single canal in all England, and her common roads were about the worst in Europe. The Flemings introduced cloth making and linen weaving, and the first windmills and watermills, while the Dutch introduced the manufactory of pottery, and the first engine for pumping purposes. The first cannon cast in Sussex county was cast by a Frenchman, and the great level of the Fens was drained by Vermuyden, a native of Zealand. A German established the first paper mill at Dartforth, and the first mines were worked by Germans under the reign of Queen Elizabeth.

In the latter part of the eighteenth century attention was directed to the betterment of her highways and internal improvements, and, from this period on, her native engineers have constructed a magnificent system of canals, turnpike roads, bridges and railways. They have built lighthouses (finger posts of the sea) around the coast.

They have hewn out and built docks and harbors for the accommodation of a gigantic commerce, whilst their inventive genius has rendered iron, fire and water the most untiring workers in all branches of industry, and the most effective agents in locomotion by land and sea.

The progress of engineering science in America from 1775 to 1825 was largely directed by Frenchmen who came to this country at the solicitation of our Government. The geological features of America, comprehending its sheltered harbors, mighty rivers and lakes, lofty and wooded mountains and boundless prairies, have offered special difficulties which have been overcome by the skill of her engineers, and their monuments are typical of our advanced civilization, our bridges, our high and colossal buildings, our vast system of railways, the improvement of our waterways and harbors, the reclamation of our lands from overflow, our electric railways and electric lighting, and other municipal and industrial works. In these things are embodied the most distinguished achievements of the American spirit, the development of which has been achieved in the last fifty years, and, if the progress of engineering science in the future continues, as in the last half century, increasing and extending the benefits resulting from the works of our engineers, they will justly be regarded as ranking among the greatest benefactors of their country.

Engineers' Club of St. Louis.

488TH MEETING, APRIL 5, 1899.—The meeting was called to order at 8.15 P.M. by President Colby. Thirty-one members and ten visitors were present. The minutes of the 487th meeting were read and approved. The minutes of the 272d meeting of the Executive Committee were read. The name of Mr. Hiram Phillips having been recommended by the Executive Committee, he was balloted for and declared elected a member of the Club. Mr. W. A. Layman then read the paper of the evening, entitled "Alternating Current Power Motors." The various uses to which motors may be put were mentioned. Ten years ago alternating current motors were regarded as mere laboratory playthings, whereas to-day they are of commercial importance. The use of the great Niagara Falls power plant for supplying current for power purposes is an illustration of the growth of the use of this type of motors.

The difference between the direct and alternating currents, and the methods of generating currents of several phases, were described and illustrated by means of diagrams. The development of the induction motor by Tesla and the results of his investigations were pointed out. While there have been many types of two and three-phase motors brought out, there has not been, until lately, a successful single-phase motor. A motor of this type is highly desirable because of its applicability to the common lighting circuit, and because it necessitates no change in the power house equipment. The essential differences between the single and multiphase motors, and the details of a successful single-phase motor as built in St. Louis, were fully described. Some interesting results of tests on a 5 horse power motor were illustrated graphically by diagrams. The discussion following was participated in by Messrs. Flad, Bryan, Humphrey, Colby, Nipher, Pillsbury and Borden. After a few remarks by the President concerning the next meeting, and the announcement of the paper for that evening, "The Engineers' Club of St. Louis, Its History and Work," by Mr. W. H. Bryan, the meeting adjourned.

E. R. FISH, *Secretary.*

489TH MEETING, APRIL 19, 1899.—The members of the Club assembled at the Southern Hotel at 7.30, and at about 8 P.M. entered the main dining room, where a course dinner was served. After dinner the meeting was held in the grand parlor, being called to order at 9.30 P.M. by President Colby. Forty-four members and forty visitors were present. As the meeting had been arranged in celebration of the 30th anniversary of the Club's incorporation, the usual routine business was omitted. The program was as follows:

Piano solo .... Miss Cora E. Fish
Remarks by the President .... Mr. B. H. Colby
Vocal solo .... Mrs. Alice Waite Perkins
The Engineers' Club of St. Louis, Its History and Work.. Mr. W. H. Bryan
Vocal solo .... Mr. W. H. Jones

Remarks by Members.

Vocal solo .... Mr. W. H. Jones

War Scenes.

Vocal solo .... Mr. J. A. Laird

Mr. Bryan's paper was the main feature of the evening. It gave the history of the Club from its inception, and also notes on each of the Past-Presidents, charter members and other prominent persons who have been connected with the Club, telling something of each one's work. Portraits were shown of all by means of a stereopticon, and in many cases some of the principal works with which they had been identified. The paper was very complete and is a valuable addition to the records of the Club.

The remarks by members consisted of short reminiscences, Mr. Wm. Wise, Mr. R. E. McMath, Prof. C. M. Woodward, Mr. M. L. Holman and Col. E. D. Meier being called upon and responding. A congratulatory telegram from Mr. Wm. Eimbeck, one of the charter members, was read. Owing to the lateness of the hour the war scenes were omitted. After a humorous song by Mr. Laird, the meeting adjourned at 11.30 P.M., having been entirely successful and most thoroughly enjoyed by all present.

E. R. Fish, *Secretary.*

Detroit Engineering Society.

The 38th regular meeting of the Society was held in the smaller lecture room of the Detroit Art Museum, Friday, March 24, 1899; President Geo. Y. Wisner presided. There were about one hundred and ten members and guests, including many ladies, present. The paper of the evening, "Locks and Lock Gates for Ship Canals," was read by the author, Mr. Henry Goldmark. It was illustrated by eighteen lantern slides, made mainly from photographs of the locks at Sault Ste. Marie, Mich.

Adjourned.

Henry Goldmark, *Secretary.*

A special meeting of the Society was held at the Hotel Ste. Claire Friday, April 7, 1899; First Vice-President W. J. Keep presided. Mr. W. C. King was elected to resident membership. The evening was devoted to a discussion on "Locks and Lock Gates for Ship Canals." It was opened by Mr. Henry Goldmark and participated in by Messrs. Woodard, Dunlap, Himes, Pope, E. Molitor, D. Molitor and Russel.

Adjourned.

Henry Goldmark, *Secretary.*

The thirty-ninth regular meeting (fifth annual meeting) of the Society was held at the Hotel Ste. Claire, Friday, April 21, 1899. President G. Y. Wisner presided, and there were forty-two members and guests present.

The annual election of officers was held, and resulted in the choice of the following officers for 1899-1900:

President—W. J. Keep.

First Vice-President—Alex. Dow.

Second Vice-President—Willard Pope.

Secretary—Henry Goldmark.

Treasurer—P. H. Hinchman, Jr.

At the close of the business meeting the members and guests adjourned to the dining room and partook of the annual banquet.

The tables were arranged as in preceding year in the form of an open square.

Informal addresses were made by the retiring President, Mr. G. Y. Wisner, by Profs. C. E. Greene and M. E. Cooley, of the University of

Michigan; by Mr. C. S. Harrison, of Chicago; Mr. E. E. Haskell, Mr. David A. Molitor, Mr. Alex. Dow, Mr. H. Goldmark, the President-elect, Mr. W. J. Keep and by Mr. G. S. Williams, the late Secretary, who was warmly welcomed to the meeting.

Adjournment did not take place till the small hours.

Henry Goldmark, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, April 7, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved. The following were elected to membership, by ballot: Members—Geo. N. Randle, assistant engineer, Board of Public Works, Sacramento; W. C. Elsemore, city engineer, Eureka; H. A. Brigham, mining engineer, San Francisco: Walter de Buxton, assistant engineer Santa Fe Railroad, Arizona. Associates—F. E. Knowles, San Francisco; J. W. Miller, San Francisco.

Mr. Marsden Manson read a paper, entitled "Notes on the Relation Between the Geology of Catchment Areas and Disease," which was discussed.

The President welcomed to the Society Mr. F. C. Prindle, civil engineer, U. S. Navy. who visited the rooms, and discussed Mr. Manson's paper, relating certain conditions of wells now boring at Goat Island for the Naval Training Station.

Adjourned.

Otto von Geldern, *Secretary.*

Civil Engineers' Club of Cleveland.

The regular meeting was held at Case School of Applied Science on April 11, 1899.

The laboratories were open at 7 o'clock and were visited by many members and friends. The new 100-ton testing machine and the steam turbine received special attention.

The meeting was called to order at 8.15 p.m. in the Electricity Building by Vice-President John W. Langley. Present, thirty-three members and fifteen visitors.

Mr. N. P. Bowler moved that the reading of the minutes be omitted; seconded by Mr. J. N. Coffin, and carried.

Messrs. H. M. Lucas and C. O. Palmer were appointed to canvass the ballots for the election to active membership of Ernest Starr Jackson and Howard P. Fairfield.

A letter from Mr. Ambrose Swasey was read containing the announcement that he had presented the Club with a new projection lantern. Dr. Chas. S. Howe moved a vote of thanks to Mr. Swasey. Many seconds were offered. Carried.

A letter from Mrs. Kimball was read, in which she thanked the Club for the expression of sympathy given at the time of the death of Mr. Hiram Kimball.

Dr. Chas. S. Howe, of the House Committee, reported that rooms had been rented in the Arcade for the joint use of the Technical Clubs, that they were now being decorated and furnished and would be ready for occupancy about May 1.

Mr. F. S. Barnum, of the Banquet Committee, reported progress, but that the arrangements were not yet completed.

Prof. Chas. H. Benjamin then read the paper of the evening, entitled "The Power Consumed by Shafting and Belts." It was illustrated by slides.

The experiments described in the paper were made on the shafting and belts used to drive the machine shop at the school, by the aid of a Flather recording dynamometer.

The dynamometer itself was shown, being driven by a motor in such a manner as to show its operation.

Copies of the diagrams drawn by this machine were shown on the screen, as well as tables giving the powers consumed by the different machines and the shafting in the shop.

In these experiments the horse power required to drive the shaft alone was found to be about one-third that required for shaft, belts and loose pulleys. The effect of flooding the shaft bearings with oil was clearly shown on the diagram.

When the shop was run under ordinary conditions the friction of the shafting and belts was found to consume more than half of the total power.

When the machines were worked to their full capacity the power was distributed about as follows:

Cutting metal	43	per cent.
Empty machines	32	"
Shafting and belts	25	"

Dynamometer cards as diagrams, from some of the machines such as lathes, planers and shapers, were then shown on the screen and explained.

After the paper was read it was discussed by Messrs. Palmer, Benjamin, Cowles, Langley and Reed.

The tellers' report was then read and the election of Ernest Starr Jackson and Howard P. Fairfield to active membership announced.

After adjournment at 9.30 lunch was served in the Mechanical Laboratory.

The semi-monthly meeting was held at the Central Manual Training School, April 25, 1899.

After an inspection of the building and equipment the meeting was called to order by President Jared A. Smith, at 8.20 P.M. Present, twenty-two members and seven visitors.

A few appropriate words were spoken by President Smith about the death of Mr. Stiles H. Curtiss, member of the Club.

The paper of the evening was then read by Mr. Lewis C. McLouth. The subject was "Manual Training," and the following is an extract:

In the early times, when the country was new and the land uncultivated, it was necessary for the people to struggle hard for their living. No one could live without hard labor, and it was this labor which brought about marked advance in civilization.

The women spent the long winter evenings in knitting, spinning and weaving, while the men and boys fashioned, with crude tools, articles of use and some beauty.

Industrial handwork was an essential part of the life of the people, and that their general happiness and moral welfare depended upon it was keenly felt.

As time passed on, the home industries had to give way more and

more to other interests, and machines were introduced, depriving the hands of occupation.

After a time it began to be felt that the general health, happiness and morals of the people were not so strong as in the olden times, and educators began to reflect upon ways and means to renew the old home industries and the conclusion was reached that schools should be established for teaching manual training.

From this it will be seen that manual training is not an outgrowth of trades or trade schools, nor of commercial handicraft, neither is it a system of training based on tools, material and construction, but is a system which has grown out of and is based upon the material needs of humanity. This seems to me to be the only rational reason for putting manual training into the schools.

Shopwork is the characteristic element in the manual training school, but adding shopwork to the regular curriculum does not make a manual training high school. In some cases it has been merely tacked on, and is the shopwork of the mechanic and not of the teacher. On the contrary, manual training may and should be in living touch with all parts of the course, and in many cases might be the very backbone of it.

It is accepted as essential to the best development of the child.

Educators realize that to work with the hands makes a boy a better boy, and to-day we have a school that is more than the trade school. We cannot teach all of carpentry or forging, but must select that which is of most value to the pupil.

The demands made upon each individual, in order to fill his position in life creditably and with a fair prospect of success, are greater now than ever before. It is not likely that this general activity and progressiveness in the commercial and industrial world will cease, consequently the necessity for an education that is many-sided, that will equip the individual with intelligence, skill and power to grapple with the difficult problems of life.

Professor John D. Runkle, once President of the Boston School of Technology, said: "Public education should touch practical life in a greater number of points; it should better fit all for that sphere in life in which they are destined to find their highest happiness and well-being. It is not meant by this that our education should be lowered mentally."

While manual training schools do not aim to teach the boy or girl a trade or profession, they do train the capable hand through practice and instruction, and cultivate a practical intelligence in the individual that enables him to make a fair start in life.

If we protect the children of the very poor from the worst consequences of their condition without making paupers of them or their parents, we must continue (after the training of the kindergarten) in some way to give them study and work together.

Chas. H. Ham, of Chicago, says: "Mechanics stand the test of scrutiny better than merchants; civil engineers and architects are more competent than railway managers, lawyers, judges and legislators; ninety-seven per cent. of the merchants fail; lawyers and judges produce a most pitiable wreck of justice, and the statutes of legislators wear out in a year; but every locomotive that leaves the shop is perfect, bridges last a century and the works of architects and builders stand as monuments of skill and fidelity long after their makers are turned to dust."

Then why store the mind with facts that are useless until applied to things, and unless they are applied to things? If they are to be applied to things, why not teach the art of so applying them? An education without this is one-sided, incomplete, unscientific.

The paper was followed by a discussion by Messrs. Smith, McLouth, Howe, Langley, Reed, Benjamin, Kendall and Herman.

All supported very strongly the idea of manual training in the public schools, not only for its physical benefits, but also for its moral training and its tendency to make honest labor with the hands appear more honorable and dignified to the youth.

It was moved by Mr. Wm. Reed, and seconded by Dr. Chas. S. Howe, that a committee of three be appointed by the chair to draft resolutions upon the death of Mr. Stiles H. Curtiss.

Mr. Ambrose Swasey, Dr. Cady Staley and Mr. Edward H. Harvey were appointed.

Meeting adjourned at 9.45 P.M.

ARTHUR A. SKEELS, *Secretary.*

Montana Society of Engineers.

A REGULAR meeting of the Society was held in Helena on April 8, 1899; Mr. James S. Keerl in the chair. The minutes of the preceding meeting in the city of Butte were read and approved. Applications for membership were presented and acted upon. Messrs. Finlay McRae and W. S. Fortiner were appointed tellers to canvass the votes for membership, which showed that Clarence V. Page, of Butte, and Lewis C. Parker, of Garnet, were elected members. The proposed amendment to Article V of the By-Laws, presented at the meeting in Butte, was discussed and the Secretary directed to have same printed and sent out to be voted upon by letter ballot. The proposed change of the headquarters of the Society to Butte was discussed, all agreeing that it was advisable to make this change as soon as possible, and that the change would be for the best interests of the Society. It was advised that the President appoint a committee to draft an amendment to the Constitution and By-Laws to provide for this change, and that said committee report at the May meeting, to be held in Butte.

No further business appearing, the meeting adjourned.

A. S. HOVEY, *Secretary.*

Engineers' Club of Cincinnati.

105TH REGULAR MEETING, CINCINNATI, O., APRIL 20, 1899.—Dinner was served at 6.15 P.M. Regular meeting was called to order at 7.15 P.M.; with President Hazard in the chair, and seventeen members present.

Minutes of the meeting of March 16 were read and approved.

Applications for associate membership were received from C. H. Davidson, of the Cincinnati Granitoid Co., and Wm. E. Green, representative of the Warren & Webster Co. and the Jewell Filter Co.

The following new members were elected: Messrs. L. S. Rose, Chas. L. Parmelee, Wm. E. Gunn, Chas. A. Knowlton and John A. Hiller.

The committee to prepare a memoir to Fred. C. Weir reported that the same would be ready for presentation at the next meeting.

Mr. Elzner, as editor of the "Question Box," read communications from two of our absent members, Messrs. Chas. A. Ewing and Hugo Diemer, which contained matter of interest.

The paper for the evening was read by Mr. A. O. Elzner on the subject, "The Development of Church Architecture," which was illustrated by numerous cuts, plates and photographs, and was quite thoroughly but informally discussed.

Adjourned.

J. F. Wilson, *Secretary.*

Association of Engineering Societies.

Vol. XXII. | May, 1899. | No. 5.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

A Review of its Past, with Some Suggestions Regarding its Future.

Annual Address by Frank C. Osborn, Retiring President, March 14, 1899.

On the evening of February 28, 1880, eleven engineers, Messrs. S. J. Baker, C. H. Burgess, John B. Davis, G. Geuder, G. Lindenthal, A. Mordecai, J. S. Oviatt, Hosea Paul, Walter P. Rice, J. Wainwright and C. N. Walter, met at the office of the County Surveyor for the purpose of organizing for mutual improvement and for social intercourse a club or society to be known as a civil engineers' club, or engineering society, as the corporate members might decide, the organization to include such of the civil engineers of Cleveland and vicinity as might choose to connect themselves therewith.

A very decided difference of opinion appearing among those present, the following resolution was offered by Mr. Paul, and adopted by the meeting with the understanding that the action of the meeting should in no way control a full discussion of the resolution at a future meeting:

"*Resolved,* That the active membership of this Society be restricted to civil engineers."

On March 9, 1880, the Constitution was adopted with the exception of but one clause, that governing the name of the organization, the committee having been given until the next meeting to report.

On March 13, 1880, Mr. Mordecai, chairman of the committee, reported in favor of adopting the name "The Engineers' Club of Cleveland." Mr. Rice presented a minority report favoring the name "The Civil Engineers' Club of Cleveland." The minority report was adopted. At this meeting the first officers of the Club were elected.

The following is a list of the charter members: Samuel J. Baker, Clarence M. Barber, C. H. Burgess, H. M. Claflin, John D. Crehore, Robert Cudell, John B. Davis, Otto Dercum, G. Geuder, A. S. Hovey, G. A. Hyde, Chas. Latimer, G. Lindenthal, A. Mordecai, Jas. S. Oviatt, Chas. Paine, Hosea Paul, M. E. Rawson, Wm. Reuchel, Walter P. Rice, Simeon Sheldon, Chas. H. Strong, E. O. Schwagerl, John Wainwright,

Chas. A. Walter, A. M. Wellington; a total of twenty-six names. Nine of these, Messrs. Baker, Barber, Claflin, Dercum, Mordecai, Paul, Rawson, Rice and Strong, are still active members. Mr. Lindenthal is now a corresponding member, Mr. Paine an honorary member; Messrs. Crehore, Cudell, Latimer, Oviatt, Sheldon and Walter died while members of the Club; Mr. Wellington was not a member of the Club at the time of his death. Of the remaining eight charter members, five, Messrs. Geuder, Reuschel, Burgess, Davis and G. A. Hyde, are still residents of the city and in active service. Messrs. Hovey, Schwagerl and Wainwright have removed from the city and are no longer connected with the Club.

On the 27th of March, 1880, a special meeting was held in the Board of Education rooms. President Charles Paine delivered an inaugural address to an audience of about one hundred persons, many of whom were ladies.

April 3, 1880, was a banner meeting for admission of members, forty-five being elected by acclamation. At this meeting a committee was directed to open up a correspondence with other similar societies in regard to a common publication.

On June 5, 1880, a Committee on Quarters reported in favor of a room in Case Library.

The Society lost its first member by death January 4 1881, in the person of Gen. Chas. B. Stewart.

On January 8, 1881, resolutions were passed leading to the publication of a joint pamphlet with the Boston, Chicago and St. Louis Societies. At this meeting also the dues were raised from $4.00 to $6.00, the increased figure to include Case Library membership fee.

On April 2, 1881, the Club met for the first time in its room in the rear of the newspaper room at Case Library. At this meeting the regular meeting night was changed from the first Saturday to the second Tuesday of each month.

At the meeting of May 29, 1881, President Chas. Paine proposed the establishment of a public bench mark of known elevation above sea level, and a committee was appointed to look into the matter.

On September 14, 1881, Mr. Paine resigned his membership on account of removal from the city. He was succeeded as President by Col. John M. Wilson. Mr. Paine took a great interest in the Club, donating many books and giving his time very freely to further its best interests.

March 11, 1882, appears to be the first record of our customary annual banquet. The Club dined at the rooms of the Windsor Club, listened to the annual address, other papers and remarks.

In June, 1882, the Engineers' Society of Western Pennsylvania, headquarters at Pittsburg, visited Cleveland, and was entertained by this Club.

On October 13, 1882, a reception was tendered Col. John M. Wilson, the occasion being his departure to Washington on account of his promotion.

He now holds the rank of Brigadier-General and the position of Chief of Engineers in the United States Army. He is still an honorary member of the Club and greatly interested in its welfare. He donated many books and maps, and long ago listed the name of the Club for all publications of the United States Engineers' Department.

On June 12, 1883, this Club joined with the American Society of Mechanical Engineers in the opening session of their annual convention in this city.

On February 12, 1884, by resolution offered by Mr. Rice, a committee was appointed to investigate the subject of pavements in various cities.

On April 20, 1884, the Club was favored with a poem by Mr. John H. Sargeant, the title being "The Three Seventies, 1814, 1884, 1954."

On June 25, 1884, the American Institute of Mining Engineers held a convention here, and this Club extended proper courtesies.

On July 8, 1884, information reached this Society that the Western Society of Engineers contemplated withdrawing from the Association of Engineering Societies. The Club immediately took the matter up, asking the Western Society to reconsider taking such action. This action of the Club probably had some weight with the Chicago Society, as they did not at that time withdraw from the Association. They did, however, withdraw during the year 1895.

On April 14, 1885, a resolution was adopted to procure cabinet photographs of members removed by death or otherwise, with a suitable case or frame for same. At this meeting action was taken regarding the placing of civil engineers on an equal footing with military engineers in public works other than military.

On August 11, 1885, Lord Sackville Cecil, Manager London District Underground Railroad, gave the Club a talk on the subject of the operation of that road.

On December 3, 4 and 5, 1885, a convention was held here of delegates from various societies in consideration of the relation of civil and military engineers on public works. Twenty-five societies were represented, and this Club took the initiative and a prominent part in the deliberation.

In the spring of 1886 a paper was read by Mr. Ritchie on "The Garfield Monument." Quite an interesting discussion resulted on the subject of the engineering problems involved. A committee was appointed to investigate the subject, which committee was very well treated by Mr. Wade and others.

On January 11, 1887, a committee was appointed on Standard Time, and rendered a report on January 25, at which time a committee was appointed to confer with the City Council.

On March 22, 1887, Mr. Sargeant read a paper on "Street Pavements, Past, Present and Future." A number of letters from various cities on the subject of pavements proved interesting and valuable.

At the next meeting April 12, 1887, an interesting discussion took place on the subject of pavements.

On February 14, 1888, resolutions were adopted regarding the appointment of civil engineers on public works.

On October 8, 1889, the question of affiliation with the American Society of Civil Engineers was taken up, discussed and referred to a committee.

March 11, 1890, was the date of the tenth annual meeting. The President called particular attention to the excellent condition of the Club, and the Secretary's report showed that there had been no resignations and no deaths for that year.

On March 27, 1890, the tenth annual banquet was held at the Kennard House, about two hundred members and guests being present.

On April 8, 1890, President Searles spoke of the need for more commodious quarters. A committee to investigate the question of larger quarters was appointed, and continued to serve for about two years, but no

definite action was taken. At this meeting Mr. Eisemann reported that the Chapter of Architects wished to affiliate with this Club for joint use of rooms and other purposes. At this meeting a communication was read from the American Society of Civil Engineers asking for the appointment of a committee for a conference regarding affiliation.

On July 8, 1890, a report was received from Mr. Holloway, who represented the Club at the conference in New York on the subject of affiliation with the American Society of Civil Engineers, to the effect that the attendance was small and nothing was accomplished.

On September 9, 1890, the third Tuesday in October was set aside for the purpose of visiting certain manufacturing plants in a body. The Club on that day visited the Cleveland City Forge Works, the Brown Hoisting and Conveying Machine Company and the Otis Steel Company.

On March 10, 1891, a new Constitution, substantially as compiled by Mr. Searles, was adopted by ballot. It was reported at this meeting that the Club owned one hundred and forty-two bound volumes in the library and two hundred pamphlets.

On May 12, 1891, the Executive Board was instructed to have the Club incorporated. This was done as soon as practicable, the date of incorporation being May 29, 1891. At this meeting there was some discussion about changing the name of the Club before incorporation, but no action was taken.

September 29, 1891, was a visiting day. The Club visited the City Water Works Pumping Station, Globe Iron Works, Shipowners' Dry Dock and Walker Mfg. Co.

November 4, 1891, was another visiting day. The Club visited the Cleveland Rolling Mills, after having taken supper at the Forest City House. The Club also visited the power house of what was then the Broadway and Newburgh Street Railway Company.

March 8, 1892, was the twelfth annual meeting. The Secretary reported that the largest attendance during the year was sixty, average thirty-five, and smallest attendance twenty. The Treasurer's report was not so favorable, as it indicated a deficit of $46.70.

At the meeting of July 12, 1892, Prof. Howe discussed statistics of the census reports from 1820 to 1880, deducing therefrom a formula for the future population of Cleveland. Prof. Howe's formula gives for the population of Cleveland in 1900, 396,587. A fair estimate for the population of Cleveland at this time would be 375,000.

At the annual meeting on March 14, 1893, there was quite an interesting discussion as to whether wine should be served at the annual banquet or not. The question was finally referred to letter ballot, the result of which was to the effect that wine be not served. Considerable feeling was aroused by the result of the discussion, and the result was that no banquet was held. At this time steps were being taken toward the remodeling of the Case Building, and there was talk of more commodious quarters for the Club in connection with the new building.

On March 13, 1894, the annual meeting was held at the Chamber of Commerce rooms, the Case Library Building being remodeled at this time. The Secretary's report showed a membership of one hundred and eighty-eight and an average attendance for the year of forty.

Early in May, this year, the Club visited the power house of the Big Consolidated Electric Railway.

On February 12, 1895, the Club met again in Case Library for the first time for a year. On February 12, 1895, the dues were increased to $10.00 by amendment to the Constitution.

At the annual meeting, March 12, 1895, the Secretary's report showed a total membership of one hundred and eighty-one, a loss of seven from the previous year.

On February 25, 1896, the Club took favorable action concerning the adoption of the metric system. This action was taken in response to a request from the House of Representatives.

At the annual meeting in March, 1896, the Secretary's report showed a total membership of one hundred and sixty-four; four new members were elected, fourteen members dropped from the rolls for non-payment of dues and six resignations were received. Notwithstanding the drop in membership, the average attendance was forty-eight.

During the winter of 1896-97 considerable work was done by a committee toward the formation of a proposed academy of science. The committee reported on February 9, 1897, to the effect that it was not to the interest of the Club to pursue the question further at that time.

The annual meeting, March, 1897, showed a membership of one hundred and ninety-one and an average attendance of fifty-five and one-half.

At a special meeting, April 6, 1897, a very able report was presented by the Committee on New Quarters, which consisted of Messrs. Searles, Miller, Swasey, Gobeille and Howe. This committee reviewed the career of the Club at some length, and argued strongly in favor of the plan for the purchase of a house. The plan suggested, however, was not carried out. The idea, though, was not entirely given up, and on February 22, 1898, at the semi-monthly meeting, the special order of business was the report of the Committee on New Quarters. After very long and thorough discussion, the committee was continued.

At the annual meeting, March 8, 1898, the Secretary's report showed a membership of one hundred and ninety and an average attendance for the year of thirty-five members and six visitors. The house question was still under discussion.

On April 13, 1898, the Club visited the new plant of the Cleveland Shipbuilding Company, the occasion being the launching of the steamer "Superior City."

Regular meetings were held right through the summer, and considerable discussion was carried on regarding a change of name. The discussion finally resulted in leaving the name of the Club as it always has been.

On December 13, 1898, the question of new quarters in the Chamber of Commerce Building was taken up, and before a lease was entered into the matter took a different shape. rooms in the Arcade coming into the argument, so that it is still uncertain where the Club will be quartered in the future.

Probably the most important matter before the Club at the present time is the question of uniting with three other Cleveland societies—viz, the Electric Club, the Chemical Society and the Architectural Club—in the occupation of common quarters. The prospect for the consummation of this project is at present very encouraging, and it is hoped and believed that it will result in great good to the several societies, as such, as well as to the individual members thereof. The publishing of a joint bulletin will

advise each member of each society of the coming meetings and subjects for discussion of all four societies. This will naturally increase the attendance at all meetings, as almost any topic pertinent to one society should prove of interest to many of the members of the others. An increase of membership in all societies would naturally follow, also, as each society can offer advantages incident to the union not now possessed by the individual societies.

The coming in contact of the members of different societies is sure to be of benefit to all on account of the broadening influence which will necessarily result. In having rooms that we may feel are our own, and which will be open at all times, it is believed that a more social feeling will develop and that many of the members will be found at the rooms during leisure hours of afternoon and evening. It will be practicable also to provide for frequent informal meetings of a social character, instead of limiting ourselves to only one such occasion each year, as represented by our customary annual picnic.

The closer union of several societies will give us additional political strength, using the term in its best sense, and put us in much better shape to propose and carry through such legislation as, after full consideration and investigation, we may in our combined wisdom deem advisable. The medical and legal professions have the benefit of laws enacted in their general interests. Is it not feasible to have similar laws enacted in the interest of the engineer? Proper legislation would benefit not only the engineer, but would be of advantage also to the client, whether individual, corporation or municipality. A quack engineer is, if anything, a more dangerous thing than a quack doctor. The latter has in general but a single life at stake, while the engineer is responsible for the safety of thousands of human beings who are compelled to traverse his structures. The health of entire communities depends largely on the proper source of water supply and on a properly designed and constructed system of sewerage.

Immense sums of money are continually being spent in carrying out the designs of engineers, and much of it spent under their direct supervision. How important it is, then, that the engineer be qualified by previous training and experience to design skillfully and to execute promptly, economically and honestly. Is not the chief engineer of a great railway system as important an official as the general counsel? And has he not as great responsibilities? Is not the chief engineer of a muncipality, whose duty requires him to design and superintend the construction of sewers, streets, water works, bridges and other works, amounting to thousands of dollars in cost, as important an official as the health officer? The answer to these questions must surely be an affirmative one, and leads naturally to the suggestion that this Club should at an early date take up the question of legislation, ascertain what has already been done in this and other States for this and other professions and formulate some plan of securing to Ohio engineers at least the legal standing and protection to which by right they are entitled.

The question of compensation for the engineer in independent practice is an important one. The architects have a schedule of prices for different classes of work which is apparently satisfactory and which is generally adhered to by the better class of architects. It would be idle to say all architects adhere to the schedule. All engineers would not adhere to a schedule if they had one. The schedule would be a standard, however, and

would probably be adhered to by the better class of engineers. It would tend to educate the public to a proper valuation of the engineer's services. It would increase the respect of engineers for their own work. If anything is ever done in this direction, somebody must start the movement. The suggestion is ventured that the Civil Engineers' Club of Cleveland take the initiative.

This Club, to make the most of its opportunities, should enlist in its ranks as many as possible of the local engineers and others who are qualified for membership. The list of associate members in particular could be largely increased by a properly organized effort. A Committee on Membership could do a great deal of good by looking up the names of men who would be desirable as members and bringing the Club to their attention. This committee could be of value also in seeing that newly-elected members are introduced to the officers and other members of the Club.

The resolution of April 14, 1885, providing for the obtaining of photographs of members removed by death or otherwise was a good one, and should be put into effect. It might be improved upon by obtaining as well the photographs of the most prominent members of the Society who are still with us.

The visiting days formerly in vogue were of much interest and value, both from a professional and from a social standpoint, and as there are still a number of places that could be profitably visited, it is to be hoped that these excursions will be revived.

The records show that the Club has from the start been progressive and public spirited, taking a proper interest in local questions as they came up. This spirit should, of course, be cultivated and the Club should do its utmost to make its importance felt and appreciated in this vicinity. A local society such as ours has before it a field of usefulness not enjoyed by the national societies, and a part of our duty should be to educate the public to a proper realization of the importance of the engineering profession, using this term in the broadest possible sense. That the profession is not appreciated as it should be is not the fault of the public, but the fault of the engineers themselves. The public is willing to learn, but must have a teacher, and the local engineering societies should assume the position of instructor. One of the first lessons ought to be the establishment of a code of ethics. The societies owe this to themselves as well as to the general public. The subject has been brought before at least one of the national societies and has been before several of the local societies, including our own, but so far nothing tangible has resulted. It is time some organization took the lead in making an effort in this direction, and the suggestion is made that the Civil Engineers' Club of Cleveland assume such leadership and gain the credit of carrying the matter to completion.

A few words from a paper read before the Boston Society, March 15, 1893, by Mr. A. W. Locke, are as applicable now as then:

"If they want things they must demand them and take means to enforce their demands. They should act together for their own common good. The engineering society should not be for the sole purpose of exchanging experiences, but rather to strengthen the position of its members and to uphold their dignity and to influence public opinion for their benefit. On all public questions affecting the interests of engineers, the society should act as a unit and make itself heard and felt. The requirements for full entrance should be severe and high, and the society should establish for

its members their minimum fees and regulate, so far as practicable, their relations to each other and to their clients. It should throw over them a mantle of protection and discourage the process by which the client is enabled to crowd down the fees by inducing engineers to bid against each other on the same work.

"By the enforcement of some such improvements as are above set forth in the relations of the engineer to his client, both parties would be benefited, and also the whole community would reap the advantage of better work and, in many cases, a more economical use of money."

Let us give our time and efforts freely to the best interests of the Civil Engineers' Club of Cleveland. Let us have in mind Section 2 of our Constitution, "The objects of the Club shall be the professional improvement of its members, the encouragement of social intercourse among them and the advancement of engineering science." Let us make this Club a model for other local societies, and let us be the first local club to have a creditable home of our own, suited to our professional and social needs in every way. We can do this if we will; let us say we will. Let us not only hope and pray, but *work* to this end.

In conclusion, I wish to thank the members of the Club for the honor bestowed upon me and to ask that the same kindly support and courtesy be extended to my successor in office as has so freely been given to me.

Annual Meeting, March 14, 1899.—The meeting was called to order at 8 o'clock; President Osborn in the chair. Present, thirty-five members and two visitors. The chair appointed Messrs. John N. Coffin and John L. Culley tellers to canvass the ballots for members and for officers for the ensuing year. The minutes of the last meeting were read. Mr. Hyde disclaimed making one remark as recorded, and, on motion of Mr. Ritchie, the sentence was struck out.

The Executive Board recommended to ballot the names of Howard P. Fairfield and Ernest Starr Jackson, applicants for admission as active members. It reported the following resignations as accepted: Wendell P. Brown, Chas. F. Mabery, Harry B. Strong, E. Ernest Rose, Valentine S. Ives, Sidney H. Short, active members, and Wm. C. Jewett, corresponding member.

Three active members, John P. Leeper, Chas. E. Webster and W. H. Bone, have been transferred to corresponding membership. Mr. S. T. Dodd has been elected by the board to fill the vacancy caused by the resignation of Ralph A. Harman as Director.

Mr. Harry L. Andrus has been appointed by the board as advertising agent.

The board announced the death of Mr. Hiram Kimball, which took place on the 9th instant.

Under the head of "Correspondence," a report from the Engineers' Club of Cincinnati was quoted from, indicating the amount of work done by that Club during the past year. A letter was read from Mr. A. J. Robinson, Secretary of the Association of Civil Engineers and Surveyors of Oklahoma Territory.

The President then read the annual report of the Executive Board, which was followed by the annual reports of the Secretary, Treasurer and Librarian. On motion, these reports were accepted.

Mr. A. L. Hyde read the annual report of the Program Committee, which, on motion, was ordered accepted and filed.

The President then read the tellers reports and announced the election to active membership of Allan Wadsworth Carpenter, and of the entire ballot for officers,—viz, Jared A. Smith, President; John W. Langley, Vice-President; Arthur A. Skeels, Secretary; John N. Coffin, Treasurer; Wm. E. Reed, Librarian; Jos. R. Oldham and Wm. B. Hanlon, Directors.

The announcement was greeted with applause.

The report of the Committee on Federation, appointed at the last meeting, was presented by Dr. Howe. It consisted of the minutes of the Joint Committee, and contained nine sections, providing for the joint occupation of rooms for two years by the several Clubs, and for a House Committee, which shall have sole charge of all details of the selection and furnishing of rooms, and expenditure of joint funds in maintaining them; providing also for the manner of making assessments upon the several Clubs.

Mr. Ritchie, seconded by Mr. Culley, moved the adoption of the report. A second reading of the report was called for and discussion followed as the reading proceeded. The discussion was participated in by Messrs. Hoit, Warner, Hyde, Searles, Coffin, Parmley and Bowler. Dr. Howe answered many questions and defended the report of the committee. Dr. Langley then moved that the debate be closed and a vote on the question be taken. Carried. The report was adopted.

Dr. Howe moved that this Club appropriate, out of the general fund, its apportionment, a sum not to exceed three dollars per capita, to be used by the House Committee in furnishing the rooms. Seconded and carried without debate.

The Chair.—How shall the members from this Club of the House Committee be appointed?

Mr. Mordecai moved that the President make the appointments. Carried.

The President made appropriate remarks upon the death of Mr. Hiram Kimball, and Mr. Ritchie moved the appointment of a committee to prepare and report suitable resolutions upon the death of Mr. Kimball. Seconded and carried. The chair appointed Messrs. Ralph A. Harman, Horace E. Andrews and Jason A. Bidwell.

Mr. Warner moved that a vote of thanks be extended to the retiring officers for their services during the past year. Carried. Mr. Warner then made some complimentary remarks upon the manner in which the work of the Secretary's office had been conducted during the year. Mr. Osborn, on behalf of the Executive Board, seconded the remarks of Mr. Warner.

The President then delivered his annual address, entitled "The Civil Engineers' Club of Cleveland; a Review of its Past, with Some Suggestions Regarding its Future." The address was received with applause.

The newly elected officers were severally called upon to address the Club. Brief and pertinent remarks were made by Col. Smith, Prof. Langley and Messrs. Skeels, Coffin and Reed.

Dr. Howe alluded to the fact that some of the oldest members in the Club find themselves in such circumstances as to be unable to pay their dues, which are several years in arrears. Under the Constitution the Executive Board has no option except to drop such members. He therefore moved that the Executive Board be authorized to remit the annual dues

of such members, not to exceed five at any one time, as in their discretion they may see fit. Seconded by Mr. Reed and carried.

Mr. Mordecai moved that the very able address of the President be referred to the Executive Board to take such action in regard to it as they may see fit. Carried.

Mr. McLouth alluded to the fact that our present high schools are very much crowded, and advocated the establishment of at least one high school on engineering and scientific lines. He hoped that some meeting of the Club may be held at the Central Manual Training School, where the subject might be more thoroughly discussed.

At half-past ten the Club adjourned.

William H. Searles, *Secretary.*

Annual Report of the Secretary for the Year Ending February 28, 1899.

To the Executive Board of the Civil Engineers' Club of Cleveland:

Gentlemen:—I have the honor to present the following report on the membership and business of the Club for the fiscal year ending February 28, 1899:

MEMBERSHIP.

At the beginning of the year the membership consisted of 151 active members, 22 associates, 13 corresponding and 5 honorary members, a total of 191. The accessions by election have been 12 active and 1 associate member. The losses by resignation have been 11 active and 1 corresponding member, and by forfeiture 10 active, 2 associate and 1 corresponding member. There have been 7 transfers made from active to corresponding membership. As the result of these changes the membership of the Club on February 28, 1899, consisted of 135 active, 21 associate, 18 corresponding and 5 honorary members, a total of 179. The net loss in numbers is, therefore, 12. The pecuniary loss to the treasury is $235 in the delinquent dues of those who have forfeited their membership.

BUSINESS.

Following is the statement of the receipts and disbursements for the year ending February 28, 1899:

GENERAL FUND.

Receipts:

Balance on hand February 28, 1898		$160.18
Dues of current year	$1,607.50	
Dues of past years	251.00	
Subscription to Journal	3.00	
Advertising	48.00	1,909.50
		$2,069.68

Disbursements:

Publication of Journal	$219.75	
Printing (including Annual Register)	169.91	
Stationery	31.50	
Postage and express	52.15	
Stenographer	64.00	
Salaries	252.40	
Certificates of membership	8.00	
Furniture	102.00	
Case Library memberships	142.00	
Rent of Rooms	135.00	

Social account (including deficit on banquet)..........	$230.55	
General expenses (collector).........................	5.40	
		$1,412.46
Balance in hands of Treasurer......................		657.22
		$2,069.68

LIBRARY FUND.

Receipts:

Balance on hand February 28, 1898..................		$23.72
Subscriptions collected by A. L. Hyde, Librarian......	$175.00	
Subscriptions collected by W. E. Reed, Librarian.....	55.00	230.00
		$253.72

Disbursements:

Additions to library..................................	$148.60	
Balance in hands of Treasurer........................	105.12	
		$253.72

PERMANENT FUND.

Receipts:

Balance on hand February 28, 1898..................		$722.90
Fees of current year..................................	$60.00	
Interest on fund deposited...........................	29.40	89.40
Balance in hands of Treasurer February 28, 1899...		$812.30

SUMMARY OF BALANCES.

General Fund..	$657.22
Library Fund	105.12
Permanent Fund	812.30
	$1,574.64

Respectfully submitted.

William H. Searles, *Secretary.*

Annual Report of the Executive Board for the Fiscal Year Ending February 28, 1899.

[Presented at the annual meeting, March 14, 1899.]

The Executive Board, in compliance with the Constitution, presents its report for the year ending February 28, 1899:

The board has held twelve sessions during the year, with an average attendance of seven members. The business of the Club has been regularly conducted according to a code of rules adopted at the beginning of the year. Monthly reports have been submitted by the Secretary, Treasurer and Librarian, showing the condition of the Club in all particulars.

Only about one-third as many applications for membership have been received this year as last, which, taken with the usual losses, has resulted in reducing the total membership to about what it was two years ago. No change has been made in the policy or usages of the Club during the year. Seventeen meetings have been held, with an aggregate attendance of 425 members and 131 visitors, or an average of 25 members and 8 visitors. The largest meeting of the year was held on April 12, at Case School, with an attendance of 41 members and 16 visitors. The technical work of the Club has been well sustained in the number and character of the papers read and in the discussions following. The practice of serving a simple lunch after each meeting has been continued with the effect of cultivating a mutual

acquaintance and interest among such as attend, though not increasing the attendance so much as could be desired.

The carefully devised plan, submitted a year ago, for obtaining a house for the Club did not meet with the cordial support that would have made it a success, and it had to be abandoned for the present. The recent movement in favor of rented rooms has received more encouragement, so that the prospect is good for seeing the Club suitably provided for in this respect. Should the Club take such rooms as it ought to have and can pay for and suitably furnish, new life and interest would be infused and a vigorous growth would undoubtedly result.

The library is in much better shape than ever before, and is well cared for under the arrangement made with Case Library. Considerable additions in the way of valuable technical books have been made during the year, both by purchase and gift. For the coming year at least the connection with the Case Library will be continued, so far as the joint use of the libraries is concerned.

The addition of new societies to the Association and the enlarged circulation have materially reduced the assessments upon this Club for the support of the JOURNAL. The cost to us for the last four quarters, including the first quarter of 1899, is $262.25, and this is reduced to $214.25 by what we receive from advertisements. This brings the net cost to us of the JOURNAL to $1.27 per member.

An agent has recently been appointed to solicit advertisements in Cleveland for the JOURNAL, through which means, it is hoped, the JOURNAL will soon become self-supporting, so far as our share in it is concerned. This matter is earnestly commended to the favorable attention of all members and friends of the Club who have occasion to advertise. Relieved of this item of expense, the Club would devote the funds so saved to improving the library and other appointments of the Club.

For further particulars reference is made to the several official reports herewith submitted.

By order of the Executive Board.

FRANK C. OSBORN, *President.*
WM. H. SEARLES, *Secretary.*

TREASURER'S ANNUAL STATEMENT, MARCH 7, 1899.

Receipts:

1898.			
March 16.	From former Treasurer:		
	Account Permanent Fund..............	$722.90	
	" General Fund..................	160.18	
	" Library Fund................	23.72	
			$906.80
	From Society for Savings, account Permanent Fund interest............	$29.40	
	" Secretary, account Permanent Fund	60.00	
			89.40
	" Secretary, account General Fund...	$1,909.50	1,909.50
	" Mr. Hyde, Librarian, account Library Fund....................	$175.00	
	" Mr. Reed, Librarian, account Library Fund....................	55.00	230.00
			$3,135.70

Disbursements:

Secretary's vouchers Nos. 1 to 51, inclusive, account General Fund	$1,412.46	
Secretary's vouchers Nos. 1 to 10, inclusive, account Library Fund	148.60	
		$1,561.06
Balances on hand:		
Permanent Fund in Society for Savings	$812.30	
General Fund in Commercial National Bank	657.22	
Library Fund in Western Reserve National Bank	105.12	1,574.64
		$3,135.70

Approved:

JOSEPH R. OLDHAM, *Finance Committee.*

WALTER MILLER, *Treasurer.*

A REGULAR meeting of the Club was held at Case Library, May 9, 1899. Meeting was called to order at 8.15 P.M. by President Jared A. Smith. Present, twenty-three members and four visitors. Minutes of meetings of March 14, April 11 and 25 were read and approved. Application for active membership of T. B. Van Dorn was read.

A letter from Mrs. Curtiss was read in which she thanked the Club for the sympathy expressed at the time of the death of Stiles H. Curtiss, a member of the Club.

Resolutions were then read by Mr. Jason A. Bidwell on the death of Hiram Kimball. Dr. J. W. Langley moved adoption of report. Seconded and carried.

Resolutions were then read by Dr. Cady Staley on the death of Stiles Henry Curtiss. Mr. Robert Hoffman moved that the report be adopted. Carried.

Dr. Charles S. Howe, of the House Committee, reported progress and informed the Club that the new quarters would be ready in about two weeks. Mr. F. S. Barnum, of the Banquet Committee, recommended dropping banquet and having a "house warming" in the new rooms instead. Moved by Prof. C. H. Benjamin that the recommendation of the Banquet Committee be adopted. Seconded by Prof. R. H. Fernald and carried.

The President appointed Mr. A. L. Hyde and Mr. H. P. Fairfield tellers to canvass the ballots for transference of $480 from permanent fund to general fund.

Vice-President J. W. Langley was called to the chair, and Dr. C. S. Howe moved to proceed with the discussion. Seconded by Col. Jared A. Smith and carried.

The discussion on the "Desirable Qualifications in Technical School Graduates" then followed and was taken part in by Messrs. Jared A. Smith, A. W. Johnston, E. P. Roberts, Cady Staley, F. S. Barnum, C. O. Palmer, Chas. H. Benjamin, C. S. Howe, J. W. Langley and, by letter, Chas. E. Webster.

The arguments were one-sided, all the gentlemen practically agreeing upon the points of which the following is a brief outline: For a man in scientific pursuits and who expects to rise in his profession a technical education is absolutely necessary. He may acquire it by his own efforts

and be a self-made man, but the technical school will save him much valuable time and make his rise more rapid.

A technical graduate should be well trained in mathematics, especially descriptive geometry. Should know how to draw neatly, intelligently and accurately. He should know how to handle all instruments and tools. He should know where to find things and how to use them. In short, he should have a general knowledge of useful things which are difficult to learn outside of school and depend upon practical work to learn those details which can best be learned in the shop or field.

A technical graduate is not expected to be as valuable to his employer for a year or two as the man who has spent four years in actual work, instead of study, but at the end of a few years the graduate will overtake and go ahead of the other.

The President then read the teller's report, which was unanimously in favor of the transference of $480 from the permanent fund to general fund, and such transference was ordered. Meeting adjourned at 10.20 P.M.

A SEMI-MONTHLY meeting was held in Case Library, May 23, 1899. Meeting called to order by Col. Jared A. Smith at 8.10 P.M. Present, twenty-one members and eleven visitors. The paper of the evening, entitled "Concrete Fireproofing," was read by Mr. F. S. Barnum. After the paper was read it was discussed by Messrs. Briggs, Smith, Barnum, Hopkinson, Herman, Hyde, Osborn, Eisenman and Dodd. Meeting adjourned at 10.10 P.M.

ARTHUR A. SKEELS, *Secretary.*

Engineers' Club of St. Louis.

490TH MEETING, MAY 3, 1899.—The Club met May 3, 1899, at 8.20 P.M.; with Vice-President Nipher in the chair. The minutes of the 274th meeting of the Executive Committee were read. Sixteen members and one visitor were present.

Mr. Pitzman addressed the Club in regard to subscribing to the World's Fair Fund. He said that he had been requested by the Finance Committee of the St. Louis World's Fair to take the necessary steps to secure stock subscriptions from the engineers and surveyors of the city to the capital stock of the corporation to be organized under the act of Legislature for the purpose of celebrating the centennial anniversary of the Louisiana Purchase. and as he thought the great historical event of the Louisiana Purchase should be celebrated in a manner commensurate with the importance of St. Louis, the largest city in the Louisiana Purchase, and as the holding of an exposition will give great opportunities to the engineers and greatly benefit their profession, he moved that the chairman be authorized to appoint a committee of three, to solicit subscriptions from the members of the Club. The motion was carried, and the chairman appointed as members of the committee Julius Pitzman, W. H. Bryan, and E. R. Fish.

Mr. John A. Laird described the hydraulic system that will be used for moving the gate valves at the Baden Station. The system is now in use for moving the valves already in place. When the station is completed, there will be eight 36-inch and four 30-inch valves, each of which will be moved by a piston worked by hydraulic pressure in a cylinder. Oil is used as the medium for transmitting the pressure, and it is circulated by a small direct

acting steam pump. In order to save space and piping it was decided to adopt a one-pipe system, in which one pipe acts for both pressure and exhaust. There are about 600 feet of ¾-inch pipe in the system, and the pressure required to circulate the oil through the entire length varies from 25 to 50 pounds per square inch, depending upon the temperature. It sometimes takes 100 pounds pressure to start a valve, and after being started 30 to 40 pounds to lift it. The valves require no pressure to close them; but 30 pounds is put on to seat them. It is impossible to drop a valve, as the friction of the oil in the ¾-inch pipe will only let it settle down slowly. No governor is used on the pump. Stereopticon views were shown of the general arrangement of pump and cylinders for moving the valves, details of the two regulating valves, the main valves and cylinders, and several of the different valves in place.

The Secretary read an abstract of a paper by Messrs. John F. Wixford and S. B. Russell on "Chemical Tests of Cement."

Professor Nipher made a few remarks on gravitation in cosmical masses of gas. When a nebula loses heat by radiation into external space, that heat, so far as can be discovered, never returns. It travels outward with the speed of light, and the imagination is lost in conjecturing what really becomes of it. The nebula contracts, as might be expected. It gravitates towards its center of gravity. It does not contract for the same reason that a gas bag under atmospheric pressure would contract when cooled. There is no external pressure on a nebula. It apparently pulls itself together by gravitation. The remarkable thing is that the nebula becomes hotter in the operation. The operation might be described as follows: The nebula loses heat. It does work on itself. It becomes warmer. It is, however, very questionable whether it is correct to say that the gas does work on itself when gravitating together. The nature of gravitation is absolutely unknown. But it seems probable that some external and unknown system is doing work on the gas when it is gravitating into smaller volumes, or that it is being gravitated. But the action is very different from an ordinary compression. The action is on each individual atom or molecule. Nothing could be more wonderful, when closely considered, than the fact that equal masses of steam and ice have equal weights.

J. H. Kinealy, *Secretary pro tem.*

491st Meeting, May 17, 1899.—Meeting was called to order at 8.20 p.m.; President Colby presiding. Twenty-five members, no visitors, were present. The minutes of the 490th meeting were read and approved. The minutes of the 275th meeting of the Executive Committee were read. The names of E. S. Pillsbury, S. B. Way, C. N. McFarland and F. C. Faust having been recommended by the Executive Committee, were balloted for and all declared elected members of the Club.

The committee appointed to draw up resolutions on the death of Winthrop Bartlett made its report, which was accepted. The resignation of Mr. Richard McCulloch, as a member of the Board of Managers of the Association of Engineering Societies, was read and accepted. On motion, it was voted to make the election of his successor special order at next meeting.

Prof. F. E. Nipher then gave a talk on the elongation of steel bars as a function of the temperature and stress. Professor Nipher gave the equation, showing the relation of the several quantities, and discussed the equation, showing graphically the way in which the quantities varied. As data on

which to base the truth of the equation is very scant and covers only a comparatively low range of temperature, the agreement between theory and practice is not satisfactory. Special reference was made to the application to welded street railway track.

The discussion following was participated in by Messrs. Holman, Connor, Kinealy, Russell, Robert Moore, Dunaway.

Mr. Colby referred to the presence of Mr. E. L. Corthell in the city, and the plan he is advocating of having an American engineering exhibition at the Paris Exposition. One or two other plans in this connection were mentioned.

There being no further business, the meeting adjourned to another room where lunch was served.

E. R. Fish, *Secretary.*

Montana Society of Engineers.

A special meeting of the Society was held in the Art Room of the Public Library in Butte, Montana, on May 13, 1899. Meeting called to order at 9 o'clock P.M.; President Eugene Carroll in the chair. Mr. C. D. Vail acting as Secretary *pro tem.* After reading and adoption of the minutes of the preceding meeting, held in Helena, Messrs. F. W. Blackford and Samuel Barker, Jr., were appointed tellers to canvass the ballots. It was found that Messrs. Arthur W. Catlin, Oscar C. Finkelnburg and William M. McClean had been elected members of the Society, and that the proposed amendment to Article V, of the By-laws, had been carried unanimously. The principal change by this amendment being the introduction of a new section, as follows:

"Section 7. It shall be the duty of the Secretary, without further authority from the Society, to drop from the mailing list of the Journal of the Association of Engineering Societies, at the beginning of each year of the Journal, the name of any member who has not paid his dues for the preceding year, and the Secretary shall immediately call the attention of such member to this section."

The Committee on Charge of Headquarters of the Society from Helena to Butte reported and recommended amendments for the Constitution necessary to such change. The report was accepted and the Secretary instructed to prepare ballots to be cast at the next regular meeting.

An interesting letter was read from Prof. A. M. Ryon, congratulating the Society on the passage of the bill regulating the measurement of water. The present labor trouble among the builders in Butte was discussed.

No further business appearing, the meeting adjourned.

A. S. Hovey, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., April 19, 1899.—A regular meeting of the Boston Society of Civil Engineers was held in Chipman Hall, Tremont Temple, at 8 o'clock P.M.; fifty-four members and visitors present.

President C. Frank Allen, on assuming the chair, expressed his appreciation of honor conferred upon him in the election to Presidency of the Society.

The record of the last meeting was then read and approved.

Messrs. Walter E. Noble and Frank T. Westcott were elected members of the Society.

Professor Swain proposed in writing the following amendment to By-law 5: For the second paragraph substitute the words, "Of the candidates for any office, the one having the largest number of votes shall be elected. If two candidates for any office receive the same number of votes, the meeting shall proceed to ballot for such office between these two candidates, a majority of the votes cast being required to elect."

The Secretary reported for the Board of Government that it had appointed the following special committees of the Society:

On Quarters—Desmond FitzGerald, E. W. Howe, C. Frank Allen, E. W. Bowditch and Hezikiah Bissell.

On the Library—F. L. Fales, C. M. Saville, F. P. McKibben, F. H. Fay and A. D. Fuller.

On Excursions—Leonard Metcalf, H. F. Bryant, C. W. Sherman, D. T. Turner and A. B. Corthell.

Members of the Board of Managers, Association of Engineering Societies—S. E. Tinkham, *ex-officio*, J. R. Freeman, Henry Manley, Fred. Brooks and Dexter Brackett.

A communication was read from Mr. Frank L. Fales, resigning the office of Librarian on account of removal from Boston. On motion, the resignation was accepted and the President requested to appoint a committee of three to nominate a Librarian. The President has appointed as members of this committee Messrs. W. E. McClintock, R. A. Hale and A. D. Flinn.

The President announced the death of Mr. Charles H. Swan, a member of the Society, which occurred on April 17, 1899. On motion, the President was requested to appoint a committee to prepare a memoir.

Mr. William F. Williams was then introduced and gave a very interesting description of the "Construction of the New Bedford and Fairhaven Bridge." The description was illustrated by a large number of lantern views.

Adjourned.

S. E. Tinkham, *Secretary*.

Boston, Mass., May 2, 1899.—A special meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock P.M.

President C. Frank Allen in the chair and one hundred and sixty members and visitors present, including ladies.

Mr. Leonard Metcalf read a very entertaining paper describing a recent trip he had made to Porto Rico, and had thrown upon the screen a large number of lantern views of points of interest which he had visited on the island.

At the close of the reading of the paper Mr. Metcalf answered a number of inquiries with regard to Porto Rico, after which the meeting adjourned.

S. E. Tinkham, *Secretary*.

Technical Society of the Pacific Coast.

Regular Meeting, May 5, 1899.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

Application of Mr. Alexander G. McAdie, forecast official, United States Weather Bureau, San Francisco, to become an associate member, was read and referred to the Executive Committee.

Mr. Franklin C. Prindle, civil engineer, United States Navy, addressed the members on the subject of "Dry Docks, Stone *vs.* Wood," which was discussed, some facts about the Mare Island stone dry dock and its cost being stated by the Secretary.

A vote of thanks by the Society was passed for Mr. Prindle for his courtesy in entertaining the request to address the members on a subject which has aroused such general interest.

Adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of Cincinnati.

106TH REGULAR MEETING, CINCINNATI, O., MAY 18, 1899.—Dinner was served at 6.15 P.M.; seventeen members and eleven visitors being present. The regular meeting was called to order at 7.25; with President Hazard in the chair.

Minutes of the meeting of April 20 were read and approved.

On ballots being taken, Messrs. C. H. Davidson and Wm. E. Green were elected associate members.

The committee appointed to prepare a memoir of Fred. C. Weir, who died April 1, presented a sketch of the life of Mr. Weir, which was ordered received and entered on the records of the Club.

Mr. John F. Earhart, of the firm of Earhart & Richardson, color printers and lithographers, read a very interesting and instructive paper on the subject of "Color."

The program for the evening had been arranged by the President, and, in addition to the paper with which Mr. Earhart so kindly favored the Club, he had invited a few friends possessed of musical talent, who entertained the Club with vocal and instrumental selections both previous to and after the reading of Mr. Earhart's paper, which proved quite a pleasing diversion and addition to the social features of the meeting, and to whom, as well as to Mr. Earhart, the thanks of the Club were voted.

J. F. WILSON, *Secretary.*

Association of Engineering Societies.

Vol. XXII. JUNE, 1899. No. 6

PROCEEDINGS.

Engineers' Club of St. Louis.

492D Meeting, June 7, 1899.—Meeting was called to order, at 1600 Lucas Place, at 8.20 P.M.; President Colby presiding. The minutes of the 491st meeting were read and approved. The minutes of the 276th meeting of the Executive Committee were read. The name of O. J. Barwick was proposed for membership. Nominations for member of the Board of Managers of the Association of Engineering Societies were asked for, and W. A. Layman, S. E. Freeman and W. L. Garrels nominated. Messrs. Bennett and Trepp were appointed tellers and announced that Mr. Layman was elected, having received 13 out of 21 votes cast.

Prof. J. H. Kinealy then gave a talk on the Pohle Air Lift Pump. The action of the pump was illustrated by means of a small model. As there is but little literature from which to obtain data for designing, it was necessary to make a lot of experiments, and for this purpose model pumps were made of different dimensions and a series of experiments conducted. The methods of making these experiments were explained and the results given, being illustrated by curves.

Several formulæ were given and discussed. The determination of certain constants, however, is still necessary, as the formulæ and practice do not agree very well. Experiments on full-sized wells are necessary to secure data for the correct determination of these constants.

Mr. Edw. Flad made some remarks on the Pohle pumping plant at the Anheuser-Busch Brewery.

There being no further business, the meeting adjourned to another room, where lunch was served.

E. R. Fish, *Secretary.*

Montana Society of Engineers.

The regular monthly meeting of the Society was held in Helena, Mont., on June 10, 1899. Meeting called to order at 8.30 P.M.; Mr. James S. Keerl in the chair. The minutes of the preceding meeting were read and approved. The proposed amendment to the Constitution changing the headquarters of the Society to Butte was informally and freely discussed, all agreeing that this change was advisable. Since, through the absence of the Secretary, ballots had not been sent out, the Secretary was instructed to send out ballots to be canvassed at the July meeting.

The sad information of the accidental death of Mr. Henry C. Relf, a member of the Society, was announced. Mr. Relf was a resident engineer for the Northern Pacific Railway Company. While inspecting a "washout" on said railway near Plains, Mont., on June 9, he slipped and fell into the rapids of the Clark's Fork of the Columbia River and was drowned.

Messrs. Forrest J. Smith, Finlay McRae and Walter S. Fortiner were appointed to prepare resolutions to be published and transmitted to relatives and acquaintances, and it was recommended that a committee be appointed at the July meeting to prepare a memoir of the deceased.

Mr. Relf was thirty-six years old. He was engaged in the engineering department of the Northern Pacific Railway continuously from 1880 to 1888, being chiefly engaged in construction work upon the main line and branches. He was assistant engineer for the Union Pacific Railway Company from 1888 until 1891, and in the last-mentioned year was engineer and inspector of sewer construction for the city of Denver, since which time he has been assistant engineer for the Northern Pacific Railway Company, with headquarters at Tacoma, Washington. The Committee upon Resolutions presented same, and after their adoption the meeting adjourned.

A. S. Hovey, *Secretary.*

Resolutions.

Helena, Mont., June 10, 1899.

Whereas, It has pleased an all-wise Providence to remove from our midst our late member, Henry C. Relf, and

Whereas, It is but just that a fitting recognition of his many virtues should be had; therefore be it

Resolved, By the Montana Society of Engineers, that while we bow in humble submission to the will of the Most High, we do not the less regret the loss this organization has sustained by his untimely death.

Resolved, That by the death of Henry C. Relf the Society has lost a member who by his professional attainments and sterling worth had endeared himself to all who knew him, and who, had he lived, was destined to become one of the foremost civil engineers of his time.

Resolved, That the heartfelt sympathy of this association be extended to his family in this the hour of their bereavement; and be it further

Resolved, That these resolutions be spread upon the permanent records of the Society, and that a copy be sent to the grief-stricken family.

Forrest J. Smith,
Finlay McRae,
W. S. Fortiner,
Committee.

Boston Society of Civil Engineers.

Boston, Mass., May 17, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock p.m.; President C. Frank Allen in the chair. Fifty-one members and visitors present.

The records of the last meeting, and of the special meeting of May 2, were read and approved.

Messrs. Wm. Church Hawley and Charles Francis Morse were elected members of the Society, and Mr. William L. Miller an associate.

On motion of Mr. Sherman, the thanks of the Society were voted to Mr. Harry P. Nawn for courtesies extended on the occasion of the visit to the Charles River Speedway this afternoon.

The thanks of the Society were also voted to Mr. Austin Cary for his very interesting talk on the "Management of the Forests of Maine," given at the informal meeting of May 10.

Mr. Hale, for the Committee to Nominate a Librarian, reported the name of Andrew D. Fuller, and upon a ballot being taken he was unanimously elected.

The next business taken up was the amendment of By-law 5 proposed in writing at the last meeting of the Society. After considerable discussion, on motion of Mr. French, it was voted to refer the proposed amendment to a committee to report a By-law at the next meeting in proper form to be acted upon. The President appointed as a committee on the proposed By-law Messrs. G. F. Swain, F. P. Stearns and A. H. French.

Mr. Freeman C. Coffin then read the paper of the evening, entitled "Covered Reservoirs and Their Design."

The paper was discussed by Messrs. F. P. Stearns, X. H. Goodnough and F. L. Fuller.

Adjourned. S. E. Tinkham, *Secretary.*

Boston, Mass., June 21, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President C. Frank Allen in the chair. Seventy-three members and visitors present.

The record of the last meeting was read and approved.

Mr. Leon S. Griswold was elected a member of the Society.

The President announced the appointment of the following committees:

To Prepare a Memoir of Charles E. C. Breck, Messrs. J. H. Curtis and Channing Howard.

To Prepare a Memoir of Charles H. Swan, Messrs. H. A. Carson and O. F. Clapp.

The Secretary read the following report:

The committee appointed to draft the proposed change in Section 5 for the By-laws begs leave to report as follows: We recommend that paragraph 2 of Section 5 be amended so that it shall read as follows: "Of the candidates for any office, the one having the largest number of legal votes by letter ballot shall be elected. If the ballot for any office should result in a tie, the meeting shall proceed to ballot for such office between the candidates tied for the first place, a majority of the votes cast being required to elect."

George F. Swain,
Frederic P. Stearns, *Committee.*
Alexis H. French,

Mr. Brooks asked for an explanation of the meaning of the words "for first place" in the proposed amendment, and after a brief explanation by Mr. French and discussion by Messrs. A. H. Howland, G. E. Howe and F. L. Fuller it was voted to refer the report back to the committee for a further report at a later meeting.

On motion of Mr. E. W. Howe, the thanks of the Society were voted to the New England Gas and Coke Company, to L. J. Hirt, its chief engineer, and to Dr. F. Schniewind for courtesies shown members of the Society this afternoon on the occasion of the visit to the plant of that company recently erected at Everett, Mass.

Mr. Louis J. Hirt, chief engineer of the New England Gas and Coke Company, then gave a very entertaining and instructive description of the engineering features in connection with the construction of the company's plant at Everett, Mass. The description was profusely illustrated by lantern slides.

At the conclusion of the lecture the thanks of the Society were voted to Mr. Hirt for his interesting description.

Adjourned. S. E. Tinkham, *Secretary*.

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST LOUIS.
MONTANA. ST. PAUL. DETROIT. PACIFIC COAST.
BUFFALO. LOUISIANA. CINCINNATI.

CONTENTS AND INDEX.

VOLUME XXIII.

July to December, 1899.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOHN C. TRAUTWINE, JR., *Secretary*, 257 S. FOURTH STREET, PHILADELPHIA.

CONTENTS.

VOL. XXIII, July-December, 1899.

For alphabetical index, see page v.

No. 1. JULY.

No. 2. AUGUST.

No. 3. SEPTEMBER.

No. 4. OCTOBER.

No. 5. NOVEMBER.

No. 6. DECEMBER.

INDEX.

VOL. XXIII, July-December, 1899.

The six numbers were dated as follows:

No. 1, July.	No. 3, September.	No. 5, November.
No. 2, August.	No. 4, October.	No. 6, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

List of Members of the Associated Societies.

Boston Society of Civil Engineers.

Adams, Alton D., 40 State st., Boston, Mass.
Adams, Edward P., Emery st., Medford, Mass.
Adams, Henry S., 53 State st., Room 542, Boston, Mass.
Addicks, Walter R., 24 West st., Boston, Mass.
Aiken, Charles W., 79 Milk st., Boston, Mass.
Allard, Thomas T., Boston El. Ry., 350 Atlantic ave., Boston.
Allen, Charles A., 44 Front st., Worcester, Mass.
Allen, C. Frank, Mass. Inst. of Technology, Boston, Mass.
Andrews, David H., 70 Kilby st., Boston, Mass.
Appleton, Ellery C., Metropolitan Water Board, Westboro, Mass.
Appleton, Thomas, Houghton, Mich.
Armstrong, Samuel G., Box 2139, Johannesburg, South Africa.
Aspinwall, Thomas, 120 Tremont st., Room 606, Boston, Mass.
Atwood, Joshua, 3d, 923 Tremont Bldg., Boston, Mass.
Badger, Frank S., Lowell, Mass.
Bailey, Ernest W., City Hall, Somerville, Mass.
Bailey, Frank S., 140 State House, Boston, Mass.
Bailey, William M., 23 Bow st., Beverly, Mass.
Baker, William E., 560 Dearborn ave., Chicago, Ill.
Baldwin, Loammi F., 31 Milk st., Boston, Mass.
Bancroft, Lewis M., Reading, Mass.
Barbour, Frank A., 1120 Tremont Bldg., Boston, Mass.
Barnes, Rowland H., Palmer st., Waltham, Mass.
Barnes, T. Howard, Medford, Mass.
Barnes, William T., 773 Broadway, South Boston, Mass.
Barrows, Harold K., 62 Margin st., West Newton, Mass.
Barrus, George H., 95 Milk st., Boston, Mass.
Bartlett, Arthur, City Hall, Lowell, Mass.
Bartlett, Charles H., 9 Concord Sq., Boston, Mass.
Bateman, Frederic W., Clinton, Mass.
Bateman, Luther H., 131 State House, Boston, Mass.
Baxter, Charles F., 15 Court Sq., Room 72, Boston, Mass.
Bayley, Frank A., 133 Austin st., Cambridgeport, Mass.
Bement, Robert B. C., St. Paul, Minn.
Betton, James M., Henry R. Worthington Hydraulic Wks., Brooklyn, N. Y.
Bidwell, Lawson B., South Terminal Station, Boston, Mass.
Bigelow, James F., City Hall, Marlboro, Mass.
Billings, William R., Taunton, Mass.
Bissell, H., Boston, Mass.
Blake, Francis, Auburndale, Mass.
Blake, John H., 226 Marlborough st., Boston, Mass.
Blake, Percy M., Hyde Park, Mass.
Blodgett, George W., Auburndale, Mass.
Blood, John B., Equitable Bldg., Boston, Mass.
Bolton, Edward D., 224 W. 79th st., New York, N. Y.
Borden, Philip D., P. O. Box 248, Fall River, Mass.
Botsford, Harry G., 79 McLellan st., Dorchester, Mass.
Bourne, Frank B., City Engineer's Office, Providence, R. I.
Bowditch, Ernest W., 60 Devonshire st., Boston, Mass.
Bowers, George, 359 Westford st., Lowell, Mass.
Boyd, James T., 60 State st., Boston, Mass.
Brackett, Dexter, 3 Mt. Vernon st., Boston, Mass.
Brackett, Wallace C., 101 Milk st., Boston, Mass.

Bradford, Laurence, Millbrook, Mass.
Bradley, Harry C., Westbourne st., Roslindale, Mass.
Bradley, William H., 642 Exchange Bldg., Boston, Mass.
Branch, Ernest W., Adams Bldg., Quincy, Mass.
Bray, Charles D., Tufts College, College Hill, Mass.
Brewer, Bertram, Waltham, Mass.
Brock, Nathan S., 39 Parsons st., Brighton, Mass.
Brooks, Frederick, 31 Milk st., Boston, Mass.
Brown, William M., Jr., 1 Mt. Vernon st., Boston, Mass.
Bryant, Henry F., 334 Washington st., Brookline, Mass.
Buck, Waldo E., 34 Institute road, Worchester, Mass.
Bullock, William D., City Engineer's Office, Providence, R. I.
Burke, John R., 131 State House, Boston, Mass.
Burley, Harry B., 31 Milk st., Room 63, Boston, Mass.
Burr, Thomas S., 200 Walnut st., Clinton, Mass.
Burton, Alfred E., Mass. Inst. of Technology Boston, Mass.
Buttolph, Benjamin G., 819 Banigan Bldg., Providence, R. I.
Caldwell, Frederic A., City Engineer's Office, Woonsocket, R. I.
Carney, Edward B., 39 Plymouth st., Lowell, Mass.
Carpenter, George A., 77 Meadow st., Pawtucket, R. I.
Carr, Joseph R., 466 Broadway, Chelsea, Mass.
Carson, Howard A., 20 Beacon st., Boston, Mass.
Carter, Henry H., 95 Milk st., Boston, Mass.
Carven, Christopher J., 34 Centre st., Dorchester, Mass.
Chace, George F., Taunton, Mass.
Chamberlain, Edw. G., Auburndale, Mass.
Chamberlain, Wm. G. S., Auburndale, Mass.
Chambers, Ralph H., 445 Tremont Bldg., Boston, Mass.
Chapman, William H., 12 High st., Newport, R. I.
Chase, John C., Derry, N. H.
Cheever, Albert S., Fitchburg, Mass.
Cheney, John E., City Hall, Boston, Mass.
Childs, Stephen, City Hall, West Newton, Mass.
Clapp, Otis F., City Hall, Providence, R. I.
Clapp, Sidney K., 3 Mt. Vernon st., Boston, Mass.
Clapp, Wilfred A., Box 546, Clinton, Mass.
Clarke, Eliot C., 15 Brimmer st., Boston, Mass.
Coffin, Freeman C., 53 State st., Boston, Mass.
Coggeshall, Robt. C. P., City Hall, New Bedford, Mass.
Cook, Byron I., Woonsocket, R. I.
Cook, Mayo T., 65 City Hall, Boston, Mass.
Corthell, Arthur B., 220 South Terminal Station, Boston, Mass.
Corthell, Elmer L., 27 Pine st., New York, N. Y.
Craib, Charles G., 158 Pleasant st., Winthrop, Mass.
Craigue, Joseph S., 53 State st., Room 542, Boston, Mass.
Crane, Albert S., Sault Ste. Marie, Mich.
Crowell, Alonzo K., Taunton, Mass.
Cummings, W. Warren, Everett, Mass.
Cunningham, Fred'k H., Bolton, Mass.
Cuntz, William C., 70 Kilby st., Boston, Mass.
Currier, George C., 60 City Hall, Boston, Mass.
Curtis, Greely S., 28 Mt. Vernon st., Boston, Mass.
Curtis, Joseph H., 85 Devonshire st., Boston, Mass.
Curtis, Louville, 354 Andover st., Lawrence, Mass.
Cutter, Charles R., 30 Tremont st., Boston, Mass.
Cutter, Louis F., 60 City Hall, Boston, Mass.
Cutter, Roland N., 51 City Hall, Boston, Mass.
Davis, Edmund S., 289 Lamartine st., Jamaica Plain, Mass.
Davis, Joseph P., 113 West 38th st., New York, N. Y.
Dean, Arthur W., City Hall, Nashua, N. H.
Dean, Francis W., 53 State st., Boston, Mass.
Dean, Luther, 14 City Sq., Taunton, Mass.
Dennette, Francis A., 149 Worcester st., Boston, Mass.
Desmond, John T., 210 Merrimac st., Haverhill, Mass.
De Wolf, John O., 579 Massachusetts ave., Cambridge, Mass.
Dodge, Samuel D., 29 Russell st., Arlington, Mass.
Dorr, Edgar S., 30 Tremont st., Boston, Mass.

Drake, Albert B., 164 Williams st., New Bedford, Mass.
Drew, Joseph N., 129 Huntington st., Hartford, Conn.
Drown, Thomas M., South Bethlehem, Pa.
Dunne, George C., 42 Oliver st., Boston, Mass.
Dwelley, Edwin F., 25 Baltimore st., Lynn, Mass.
Ellis, George A., 158 Sherman st., Springfield, Mass.
Ellis, John W., Woonsocket, R. I.
Ellis, S. Clarence, 1750 Beacon st., Brookline, Mass.
Ellsworth, Emory A., 7 Main st., Holyoke, Mass.
Estey, Henry W., 20 Garnet st., Malden, Mass.
Evans, George E., 95 Milk st., Boston, Mass.
Fales, Frank L., 1 Willow st., Boston, Mass.
Farnham, Fred'k W., City Engineer's Office, City Hall, Lowell, Mass.
Farnham, Irving T., West Newton, Mass.
Farnum, Loring N., 17 Central st., Boston, Mass.
Favor, William A., City Engineer's Office, Chester st., Lowell, Mass.
Fay, Frederic H., 60 City Hall, Boston, Mass.
Felton, Burton R., 1120 Tremont Bldg., Boston, Mass.
Felton, Charles R., Brockton, Mass.
Ferguson, John N., 3 Mt. Vernon st., Boston, Mass.
Fernald, George N., City Hall, Portland, Me.
Fitz, Charles F., Jr., Watertown, Mass.
FitzGerald, Desmond, 3 Mt. Vernon st., Boston, Mass.
Fletcher, Austin B., 4 Mt. Vernon st., Boston, Mass.
Flinn, Alfred D., 3 Mt. Vernon st., Boston, Mass.
Floyd, Fred G., 23 Old Court House, Boston, Mass.
Fisk, Edward P., 1 Mt. Vernon st., Boston, Mass.
Fobes, Arthur A., City Hall, Pittsfield, Mass.
Fogg, Arthur G., Hilburn st., Roslindale, Mass.
Folsom, Charles W., 30 Tremont st., Boston, Mass.
Forbes, Fayette F., Brookline, Mass.
Foss, Clifford, 3 Mt. Vernon st., Boston, Mass.
Foss, William E., 3 Mt. Vernon st., Boston, Mass.
Foster, Edward S., 624 Tremont Bldg., Boston, Mass.
Foster, Willard M., 64 Grove st., Lowell, Mass.
Francis, George B., 220 South Terminal Station, Boston, Mass.
Freeman, John R., 812 Banigan Bldg., Providence, R. I.
French, Alexis H., Town Hall, Brookline, Mass.
French, Frank B., 4 Municipal Bldg., Woburn, Mass.
French, George L. R., Beverly, Mass.
French, Heywood S., 417 Butler Exchange, Providence, R. I.
Frink, Harry A., 23 Pinckney st., Boston, Mass.
Frizell, Joseph P., 60 Congress st., Boston, Mass.
Fteley, Alphonse, 213 Stewart Bldg., New York, N. Y.
Fuller, Andrew D., 30 Tremont st., Boston, Mass.
Fuller, Frank E., Box 237, West Newton, Mass.
Fuller, Frank L., 12 Pearl st., Boston, Mass.
Fuller, Fred Vincent, 16 Dorrance st., Charlestown, Mass.
Fuller, George W., 2106 Grand ave., Walnut Hills, Cincinnati, Ohio.
Fuller, William B., 57 Lumber Dist., Albany, N. Y.
Gage, Herbert E., Chief Engineer's Office B. & A. R. R., Boston, Mass.
Gannett, Charles H., 1102 Exchange Bldg., Boston, Mass.
Gay, Charles W., 25 Exchange st., Lynn, Mass.
Gerrish, John H., 25 Congress st., Boston, Mass.
Gerry, Lyman L., Eng. Dept., Mass. Highway Commission, Stoneham, Mass.
Glover, Albert S., 714 Tremont Temple, Boston, Mass.
Goodnough, Benj. F., Brookline, Mass.
Goodnough, X. H., Room 140, State House, Boston, Mass.
Gould, John A., 24 West st., Boston, Mass.
Gowing, E. H., 95 Milk st., Boston, Mass.
Gray, Joseph P., Hunter and Putnam sts., West Newton, Mass.
Greene, Levi R., 35 Concord ave., Cambridge, Mass.
Gregg, Herman, 23 Willow st., Waltham, Mass.
Grew, Herbert L., 102 Milk st., Boston, Mass.

Grover, Arthur C., 59 Evergreen ave., Rutland, Vt.
Grover, Edmund, East Walpole, Mass.
Grover, Nathan C., University of Maine, Orono, Me.
Guppy, Benjamin W., Bridge Dept. B. & M. R. R., Boston, Mass.
Gushee, Edward G., 1942 N. 23d st., Philadelphia, Pa.
Haberstroh, Chas. E., South Framingham, Mass.
Hale, Richard A., Essex Water Power Co., Lawrence, Mass.
Hale, R. S., 31 Milk st., Boston, Mass.
Hall, Frank E., Box 124, Quincy, Mass.
Hall, George H., Jr., 5 New Millet st., Dorchester, Mass.
Hamilton, George W., 30 Tremont st., Boston, Mass.
Hamlin, George H., 92 Main st., Orono, Me.
Hammatt, Edw. A. W., 29 Pemberton Sq., Boston, Mass.
Hardy, George F., 30 Broad st., New York, N. Y.
Hardy, George R., N. Y., N. H. & H. R. R., Forest Hills, Mass.
Harrington, David A., 119 Ames Bldg., Boston, Mass.
Harrington, Ephraim, 60 State st., Boston, Mass.
Harris, Charles, 70 Kilby st., Room 68, Boston, Mass.
Harris, Isaac K., 59 Exchange st., Lynn, Mass.
Harrison, Christopher, City Hall, Everett, Mass.
Hart, Frank S., Met. Water Works, South Framington, Mass.
Harwood, T. T. Hunter, Rockport, Mass.
Haskell, John C., 49 Hawthorne st., Lynn, Mass.
Hastings, Isaac W., City Engineer's Office, West Newton, Mass.
Hastings, Lewis M., City Hall, Cambridgeport, Mass.
Haswell, Charles H., 346 Broadway, New York, N. Y.
Hatch, Arthur E., 9 High st., Boston, Mass.
Hawes, Louis E., 751 Tremont Bldg., Boston, Mass.
Hawkes, Levi G., Saugus, Mass.
Hayes, Henry W., Fitchburg R. R., Fitchburg, Mass.
Hazelton, Charles W., Turners Falls Co., Turners Falls, Mass.
Hazen, Allen, St. Paul Bldg., 220 Broadway, New York, N. Y.
Heald, Simpson C., 48 Congress st., Boston, Mass.
Hering, Rudolph, 100 William st., New York, N. Y.
Herschel, Clemens, 2 Wall st., Room 54, New York, N. Y.
Hersey, Frederic M., 60 Devonshire st., Boston, Mass.
Hews, Joseph R., 73 Charles River ave., Charlestown, Mass.
Hicks, C. Atherton, Needham, Mass.
Higgins, Herman K., 1799 Dorchester ave., Dorchester, Mass.
Hinckley, David, West Boylston, Mass.
Hodgdon, Frank W., 131 State House, Boston, Mass.
Hodges, Gilbert, 60 State st., Boston, Mass.
Holden, Horace G., Nashua, N. H.
Hollingsworth, Sumner, 44 Federal st., Boston, Mass.
Hollis, Ira N., 24 Quincy st., Cambridge, Mass.
Holmes, John A., City Hall, Cambridge, Mass.
Holt, Arthur C., 166 Devonshire st., Boston, Mass.
Hopson, Ernest G., Met. Water Board, Clinton, Mass.
Horton, Arthur E., 14 Beacon st., Boston, Mass.
Horton, Theodore, 17 Everett st., Melrose, Mass.
Hosmer, Francis E., 652 E. Third st., South Boston, Mass.
Hosmer, Sidney, 79A Ames Bldg., Boston, Mass.
Houghton, Charles E., 51 Norfolk st., Mattapan, Mass.
Howard, John L., 3 Mt. Vernon st., Boston, Mass.
Howe, Edward W., 65 City Hall, Boston, Mass.
Howe, George E., 20 Wesley Park, Somerville, Mass.
Howe, Horace J., Grand Central Station, New York, N. Y.
Howe, Will B., 2½ N. Main st., Concord, N. H.
Howland, Albert H., 60 Congress st., Boston, Mass.
Howland, Charles W., 44 Union st., Rockland, Mass.
Hubbard, Dwight L., 51 City Hall, Boston, Mass.
Hultman, Eugene C., 205 Broadway, Cambridgeport, Mass.
Hunking, Arthur W., Lindale, Floyd county, Ga.
Hunter, Frederic S., 5 City Hall, Boston, Mass.
Hunter, Henry G., Quincy, Mass.

Hyde, Charles G., 140 State House, Boston, Mass.
Jackson, William, City Hall, Boston, Mass.
Jenney, Walter, 55 G st., South Boston, Mass.
Johnson, Alpheus M., 8 Morton st., Concord, N. H.
Johnson, Frank P., 267 Crescent st., Waltham, Mass.
Johnson, James W., Riverside, Cal.
Johnson, Lewis J., 100 Avon Hill st., North Cambridge, Mass.
Johnson, William S., Room 140, State House, Boston, Mass.
Jones, J. Edwin, Jamaica Plain, Mass.
Keene, William F., 84 Cross st., Central Falls, R. I.
Keith, Herbert C., N. Y., N. H. & H. R. R., New Haven, Conn.
Kendall, Francis H., Court House, East Cambridge, Mass.
Kettell, Charles W., 19 Brewster st., Cambridge, Mass.
Kidd, Alexander L., 30 Tremont st., Boston, Mass.
Kimball, George A., 101 Milk st., Boston, Mass.
Kimball, Joseph H., City Engineer's Office, West Newton, Mass.
King, George A., City Hall, Taunton, Mass.
Knapp, Frederick B., Powder Point School, Duxbury, Mass.
Knowles, Morris, City Hall, Pittsburg, Pa.
Knowlton, Willis T., 60 Cedar st., Malden, Mass.
Lanza, Gaetano, Mass. Inst. of Technology, Boston, Mass.
Lavis, Fred, Chihuahua & Pacific R. R., Chihuahua, Mexico.
Lawton, Louis C., B. & M. R. R., Waverly, Mass.
Lawton, Perry, 7 Savings Bank Bldg., Quincy, Mass.
Learned, Wilbur F., Watertown, Mass.
Leavitt, Erasmus D., 2 Central Sq., Cambridgeport, Mass.
Leland, George I., City Hall, Lynn, Mass.
Libbey, Dana, City Engineer's Office, West Newton, Mass.
Lincoln, Edwin H., 120 Tremont st., Room 606, Boston, Mass.
Link, John William, 3 Mt. Vernon st., Boston, Mass.
Locke, Frank L., Boston Rubber Shoe Co., Malden, Mass.
Locke, Franklin B., North Adams, Mass.
Luther, William J., Water Dept., Attleboro, Mass.
Lyman, Edward, 431 Wilder st., Lowell, Mass.
Lyman, John F., P. O. Box 2295, Boston, Mass.
Lyon, Joseph P., N. Y. C. & H. R. R. R., Rochester, N. Y.
Macksey, Henry V., 710 Albany st., Boston, Mass.
Main, Charles T., 53 State st., Room 1112, Boston, Mass.
Manahan, Elmer G., 3 Mt. Vernon st., Boston, Mass.
Manley, Henry, 51 City Hall, Boston, Mass.
Manley, Laurence B., 116 Mt. Vernon st., West Roxbury, Mass.
Marble, Arthur D., City Hall, Lawrence, Mass.
Marston, Ralph E., City Engineer's Office, Lynn, Mass.
Martin, James W., 38 Oliver st., Boston, Mass.
Marvell, Edward I., 81 Bedford st., Fall River, Mass.
Mason, Charles A., 631 Massachusetts ave., Central Sq., Cambridgeport, Mass.
Mattice, Asa M., 2 Central Sq., Cambridgeport, Mass.
McAlpine, William H., 18 Abbott st., Lawrence, Mass.
McClintock, William E., 15 Court Sq., Boston, Mass.
McInnes, Frank A., 23 Salcombe st., Dorchester, Mass.
McKay, William E., 10 Pearl st., Dorchester, Mass.
McKibben, Frank P., Mass. Inst. of Technology, Boston, Mass.
Melcher, Frank O., Boston, Mass.
Metcalf, Leonard, 89 State st., Boston, Mass.
Mildram, Henry C., 23 Old Court House, Boston, Mass.
Miller, Edward F., Mass. Inst. of Technology, Boston, Mass.
Miller, Hiram A., Met. Water Board, Clinton, Mass.
Mills, Charles, 4 Mt. Vernon st., Boston, Mass.
Mills, Frank H., Woonsocket, R. I.
Miner, Franklin M., 27 Old Court House, Boston, Mass.
Mirick, George L., 7 Pleasant st., Malden, Mass.
Mitchell, Henry, Nantucket, Mass.
Moore, Arthur C., 100 Main st., Southbridge, Mass.
Morrill, George S., South Terminal Station, Boston, Mass.
Morris, Frank H., 9 Baker Park, Roxbury, Mass.

Morrison, Harry J., P. O. Box 488, Clinton, Mass.
Morrison, John W., 211 Tremont Bldg., Boston, Mass.
Morse, William P., City Hall, West Newton, Mass.
Moses, John C., 70 Kilby st., Boston, Mass.
Motte, M. Irving, 143 Federal st., Boston, Mass.
Moultrop, Irving E., 3 Head Place, Boston, Mass.
Nash, Henry A., Jr., Weymouth Heights, Mass.
Nelson, George A., City Hall, Lowell, Mass.
Nelson, William, Masonic Temple, Laconia, N. H.
Nevers, Curtis G., 14 Perrin st., Roxbury, Mass.
Nichols, Alfred E., 142 Wilder st., Lowell, Mass.
Norris, Walter H., B. & M. R. R., Boston, Mass.
Nott, Samuel, Hartford, Conn.
Nye, George H., 323 Cottage st., New Bedford, Mass.
Ober, Arthur J., Jamestown, R. I.
Oliver, M. W., 5 Albion st., Lawrence, Mass.
Olmsted, John C., Brookline, Mass.
Palmer, Alfred T., Hobart st., Brighton, Mass.
Parker, Harold, South Lancaster, Mass.
Parker, William, B. & A. R. R., Boston, Mass.
Parsons, Charles S., 50 City Hall, Boston, Mass.
Patch, Walter W., 18 Savin st., Roxbury, Mass.
Pearson, Charles A., 21 City Sq., Charlestown, Mass.
Pearson, Fred S., Met. Street Ry. Co., New York, N. Y.
Peck, Charles H., 344 Blackstone st., Providence, R. I.
Peirce, Eugene E., 138 State House, Boston, Mass.
Peirce, Frank A., Greensboro, N. C.
Perkins, Clarence A., 57 High st., Malden, Mass.
Perkins, Theodore P., B. & M. R. R., Boston, Mass.
Pettee, Eugene E., 53 State st., Room 1107, Boston, Mass.
Phillips, Henry A., 120 Tremont st., Room 503, Boston, Mass.
Pierce, Arthur G., 3 Head Place, Boston, Mass.
Pierce, Herbert F., City Engineer's Office, West Newton, Mass.
Pierce, William T., 14 Beacon st., Boston, Mass.
Plimpton, Arthur L., 101 Milk st., Boston, Mass.
Pope, Lemuel, Arlington Heights, Mass.
Pope, Macy S., 31 Milk st., Boston, Mass.
Porter, Dwight, Mass. Inst. of Technology, Boston, Mass.
Pratt, Dana M., 334 Washington st., Brookline, Mass.
Pratt, Daniel W., 60 Devonshire st., Boston, Mass.
Pratt, N. Raymond, Sudbury, Mass.
Putnam, Charles E., Jamaica Park, Jamaica Plain, Mass.
Rice, George S., 95 Milk st., Boston, Mass.
Rice, L. Frederick, 125 Milk st., Boston, Mass.
Rice, Otis D., 19 Hutchinson st., Winthrop, Mass.
Rich, Isaac, 36 Walnut st., Somerville, Mass.
Richards, Robert H., Mass. Inst. of Technology, Boston, Mass.
Richards, Walter H., New London, Conn.
Richardson, Thomas F., Met. Water Board, Clinton, Mass.
Ripley, Herbert L., 29 Hancock st., Boston, Mass.
Rollins, James W., Jr., 1007 Tremont Bldg., Boston, Mass.
Robbins, Arthur G., Mass. Inst. of Technology, Boston, Mass.
Robbins, Franklin H., 13 Waterhouse st., Cambridge, Mass.
Ross, Edward L., Indian Orchard, Mass.
Ross, Elmer W., City Engineer's Office, Providence, R. I.
Rowell, Frank B., 14 Linwood road, Lynn, Mass.
Rowell, Henry K., 141 Dale st., Waltham, Mass.
Sabine, Edward D., 628 Tremont Bldg., Boston, Mass.
Safford, Arthur T., 66 Broadway, Lowell, Mass.
Sampson, George T., South Terminal Station, Boston, Mass.
Sando, Will J., 3 Mt. Vernon st., Boston, Mass.
Sargent, Albert F., 425 Main st., Malden, Mass.
Saville, Caleb Mills, 3 Mt. Vernon st., Boston, Mass.
Saville, George G., 178 Devonshire st., Boston, Mass.
Sawyer, Edward, 60 Congress st., Boston, Mass.
Schwamb, Peter, Mass. Inst. of Technology, Boston, Mass.

Sedgwick, William T., Mass. Inst. of Technology, Boston, Mass.
Sellew, Edgar P., 23 Old Court House, Boston, Mass.
Semple, Wm. J. C., 23 Old Court House, Boston, Mass.
Servis, George O. W., City Hall, Somerville, Mass.
Shaw, Edward S., 12 Pearl st., Boston, Mass.
Shedd, George G., 26 Prospect st., Clinton, Mass.
Shedd, J. Herbert, Providence, R. I.
Shepard, Walter, 79 Bloomfield st., Dorchester, Mass.
Sherman, Charles W., 3 Mt. Vernon st., Boston, Mass.
Sherry, Frank E., 15 Court Sq., Boston, Mass.
Shirreffs, Reuben, 3 Mt. Vernon st., Boston, Mass.
Skinner, Fenwick F., 2849 Washington st., Roxbury, Mass.
Slater, Howard C., Box 423, Milwaukee, Wis.
Sleeper, George E., P. O. Box 3198, Boston, Mass.
Smilie, Edward S., Newton, Mass.
Smith, Chester W., 30 Leighton ave., Clinton, Mass.
Smith, Melvin B., 26 Hildreth Bldg., Lowell, Mass.
Smith, Sidney, 91 Maple st., West Roxbury, Mass.
Snow, F. Herbert, 1120 Tremont Bldg., Boston, Mass.
Snow, Franklin A., Brookline, Mass.
Snow, J. Parker, B. & M. R. R., Boston, Mass.
Sondericker, Jerome, Mass. Inst. of Technology, Boston, Mass.
Sonne, Otto, P. O. Box 3051, Boston, Mass.
Soper, George A., 251 West 93d st., New York, N. Y.
Spalding, Frederic P., 60 City Hall, Boston, Mass.
Spear, Walter E., 240 Chestnut st., Clinton, Mass.
Spofford, Nelson, 14 Water st., Haverhill, Mass.
Stanford, Homer R., Navy Yard, Charlestown, Mass.
Stark, William E., 38 Linnæan st., Cambridge, Mass.
Stearns, Edward B., 13 Exchange st., Boston, Mass.
Stearns, Frederic P., 3 Mt. Vernon st., Boston, Mass.
Stephenson, Frank H., 152 Chestnut st., Jamaica Plain, Mass.
Stevens, Harold C., Braintree, Mass.
Stevens, Walter C., 541 Main st., Melrose, Mass.
Stoddard, George C., 215 West 125th st., New York, N. Y.
Story, Isaac M., Boston, Mass.
Stratton, George E., 108 Ashland st., Malden, Mass.
Street, Leonard L., 145 West Newton st., Boston, Mass.
Stubbs, James H., St. Albans, Vt.
Swain, George F., Mass. Inst. of Technology, Boston, Mass.
Swan, Charles H., 25 Wabon st., Roxbury, Mass.
Sweet, Kilburn S., 2 Aspen st., Roxbury, Mass.
Swift, William E., 3 Mt. Vernon st., Boston, Mass.
Symonds, Henry A., Billerica, Mass.
Taber, James C. S., 71 Aldie st., Allston, Mass.
Taylor, Edwin A., 10 Dean st., Worcester, Mass.
Taylor, Gordon H., 1146 Tremont Bldg., Boston, Mass.
Taylor, Lucian A., 609 Tremont Bldg., Boston, Mass.
Temperley, Charles, 7 High st., Medford, Mass.
Thompson, Sanford E., 63 Hartford st., Newton Highlands, Mass.
Thorndike, Sturgis H., 60 City Hall, Boston, Mass.
Tighe, James L., Holyoke Water Works, Holyoke, Mass.
Tilden, James A., Hersey Mfg. Co., South Boston, Mass.
Tingley, Richard H., 75 Westminster st., Providence, R. I.
Tinkham, S. Everett, 60 City Hall, Boston, Mass.
Treadwell, Edward D., 124 Linden ave., Malden, Mass.
Tripp, Oscar H., Arlington Heights, Mass.
Tucker, Francis C., Deadwood, S. D.
Tucker, Lester W., 346 Summer st., West Somerville, Mass.
Turner, Daniel L., Lawrence Scientific School, Cambridge, Mass.
Turner, Edmund K., 442 Exchange Bldg., Boston, Mass.
Varney, Henry A., Room 2, Town Hall, Brookline, Mass.
Vaughan, Louis B., 100 Pembroke st., Boston, Mass.
Vickery, Gilbert S., City Hall, Bangor, Me.
Vose, George L., Paris, Me.
Waitt, Charles G., Waitt's Block, Malden, Mass.
Wales, Frederick N., 131 State House, Boston, Mass.
Walker, Elton D., 12 Gillespie st., Schenectady, N. Y.

Wallace, Chester J., 3 Mt. Vernon st., Boston, Mass.
Wallace, Frederic A., 54 Hampshire st., Lawrence, Mass.
Wallace, Joseph H., Townsend Bldg., Broadway and 25th st., New York, N. Y.
Walworth, Arthur C., 100 Pearl st., Boston, Mass.
Warren, George M., City Engineer's Office, West Newton, Mass.
Wason, Leonard C., 199 Harvard st., Brookline, Mass.
Watkins, William J., 180 Leyden, Orient Heights, East Boston, Mass.
Watson, William, 107 Marborough st., Boston, Mass.
Webb, DeWitt C., 679 Tremont st., Boston, Mass.
Webber, William O., Room 509, 53 State st., Boston, Mass.
Webber, Winslow L., City Hall, Gloucester, Mass.
Wellington, Arthur J., 237 Franklin st., Boston, Mass.
Wells, Charles E., Met. Water Board, Northborough, Mass.
Weston, Edmund B., 86 Weybosset st., Providence, R. I.
Wetherbee, George A., City Hall, Malden, Mass.
Wheeler, Bertrand T., Albion Bldg., 1 Beacon st., Boston, Mass.
Wheeler, William, 89 State st., Boston, Mass.
White, Hartley L., Braintree, Mass.
Whiting, Russell H., 334 Washington st., Brookline, Mass.
Whitney, Frank O., 27 Old Court House, Boston, Mass.
Whitney, George E., 2 Central Sq., Cambridgeport, Mass.
Whitten, Ernest P., Irving st., West Roxbury, Mass.
Whitwell, William S., 98 Chestnut st., Boston, Mass.
Wiggin, Ernest W., N. Y., N. H. & H. R. R., New Haven, Conn.
Wiggin, Thomas H., 154 Mountain ave., Malden, Mass.
Wight, Willard W., Natick, Mass.
Wilkes, Charles M., 1142 The Rookery, Chicago, Ill.
Williams, William F., 224 Pleasant st., New Bedford, Mass.
Wilson, Herbert A., 60 City Hall, Boston, Mass.
Winslow, Frederic I., 49 City Hall, Boston, Mass.
Winsor, Frank E., 17 Prospect st., Clinton, Mass.
Wood, Henry B., 138 State House, Boston, Mass.
Woodfall, J. L., 15 Court Sq., Boston, Mass.
Woodward, M. Grant, 73 Charles River ave., Charlestown, Mass.
Woods, Henry D., City Hall, West Newton, Mass.
Worcester, John, 53 State st., Boston, Mass.
Worcester, Joseph R., 53 State st., Boston, Mass.
Worthington, Erastus, Insurance Bldg., Dedham, Mass.
Young, E. Elbert, 100 Mt. Vernon st., Boston, Mass.

Civil Engineers' Club of Cleveland.

Aborn, Frank, 59 Fourth ave., Cleveland, Ohio.
Allen, George L., 1193 Euclid ave., Cleveland, Ohio.
Allen, Luther, 1695 Euclid ave., Cleveland, Ohio.
Allen, W. M., 40 Spangler ave., Cleveland, Ohio.
Anderson, N. M., 468 Giddings ave., Cleveland, Ohio.
Andrews, H. E., The Cuyahoga, Cleveland, Ohio.
Baackes, M., 712 Wilson ave., Cleveland, Ohio.
Baker, S. J., Cleveland, Ohio.
Balkwill, Stephen, Jr., 8 Van Ness ave., Cleveland, Ohio.
Bardons, Geo. C., Case ave., cor. Hamilton st., Cleveland, Ohio.
Barber, C. M., Semet-Solvay Co., Wheeling, W. Va.
Barnett, James, 697 Euclid ave., Cleveland, Ohio.
Barnum, Frank S., New England Bldg., Cleveland, Ohio.
Barren, H. A., Cleveland Rolling Mill, Cleveland, Ohio.
Bartol, George, Otis Steel Co., Ltd., Cleveland, Ohio.
Benjamin, Chas. H., 89 Adelbert st., Cleveland, Ohio.
Beardsley, Jos. C., Water Works Office, Cleveland, Ohio.

Bidle, Wm. S., 955 Detroit st., Cleveland, Ohio.
Bidwell, J. A., 139 Kensington st., Cleveland, Ohio.
Bishop, Albert C., 193 Sawtell ave., Cleveland, Ohio.
Blunt, Wm. T., Toledo, Ohio.
Boalt, E. E., 45 Outhwaite ave., Cleveland, Ohio.
Bowler, Geo. H., 216 Amer. Trust Bldg., Cleveland, Ohio.
Bone, W. H., 375 Franklin ave., Cleveland Ohio.
Bowler, N. P., 14 Winter st., Cleveland, Ohio.
Brown, A. E., 1151 Prospect st., Cleveland, Ohio.
Brown, Fayette, Perry-Payne Bldg., Cleveland, Ohio.
Brown, T. Morris, 583 Sibley st., Cleveland, Ohio.
Brown, P. Wendell, 501 Fifth ave., New York.
Burke, C. E., Lake Shore Fdy., Cleveland, Ohio.
Carpenter, C. A., Lake Shore Bldg., Cleveland, Ohio.
Chapin, L. E., Canton, Ohio.
Chisholm, Wm., Sr., 364 Case ave., Cleveland, Ohio.
Chisholm, Wm., 779 Euclid ave., Cleveland, Ohio.
Claflen, H. M., 29 Euclid ave., Cleveland, Ohio.
Cobb, Philip L., 2509 Euclid ave., Cleveland, Ohio.
Coffin, John N., 809 Western Reserve Bldg., Cleveland, Ohio.
Comstock, C. Warren, 1405 New England Bldg., Cleveland, Ohio.
Cook, C. O., 569 Case ave., Cleveland, Ohio.
Cooke, E. C., 623 Society for Savings, Cleveland, Ohio.
Corlett, John F., 411 Perry-Payne Bldg., Cleveland, Ohio.
Covert, John Sterling, 10 Isham ct., Cleveland, Ohio.
Cowles, W. L., 548 Neville st., Pittsburg, Pa.
Cowles, Wm. B., 223 Princeton st., Cleveland, Ohio.
Cox, J. D., Jr., Lake and Kirtland sts., Cleveland, Ohio.
Crouch, N. S., 240 East Eighth st., Erie, Pa.
Culley, John L., 33 Blackstone Bldg., Cleveland, Ohio.
Curtiss, S. H., 621 Prospect st., Cleveland, Ohio.
Daily, Chas. I., 281 Hough ave., Cleveland, Ohio.
Dercum, Otto, 38 City Hall, Cleveland, Ohio.
Dodd, S. T., Walker Co., Cleveland, Ohio.
Dodd, John N., Walker Co., Cleveland, Ohio.
Dunham, H. F., 2 Wall st., New York.
Dyer, H. P., Lake and Kirtland sts., Cleveland, Ohio.
Fairfield, Howard P., Case School of App. Sc., Cleveland, Ohio.
Falding, F. J., 45 Broadway, New York.
Fernald, Robert H., 366 Amesbury ave., Cleveland, Ohio.
Force, C. G., Jr., City Hall, Cleveland, Ohio.
Gibbs, Harley B., King Bridge Co., Cleveland, Ohio.
Gobeille, J. L., 26 York st., Cleveland, Ohio.
Goffing, Chas., Water Works Office, Cleveland, Ohio.
Green, B. L., The Osborn Bldg., Cleveland, Ohio.
Greene, Stanley R., 293 Forest st., Cleveland, Ohio.
Guthrie, Henry W., 117 Water st., Cleveland, Ohio.
Handy, E. A., L. S. and M. S. R. R. Bldg., Cleveland Ohio.
Hanlon, Wm. B., 825 Hickox Bldg., Cleveland, Ohio.
Harman, R. A., Cleveland City Forge and Iron Co., Cleveland, Ohio.
Harvey, Ed. H., 1150 Euclid ave., Cleveland, Ohio.
Hayes, S. W., 91 Water st., Cleveland, Ohio.
Henderer, Wm. O., Osborn Bldg., Cleveland, Ohio.
Hobbs, Dr. Perry L., Western Reserve Medical College, Cleveland, Ohio.
Hoffman, Robt., 55 Osborn st., Cleveland, Ohio.
Hoit, L. B., 24 South Water st., Cleveland, Ohio.
Hopkinson, C. W., 50 Euclid ave., Cleveland, Ohio.
Honsberg, Aug. A., 309 City Hall, Cleveland, Ohio.
Howe, Prof. Chas. S., Case School of App. Sc., Cleveland, Ohio.
Hyde, A. Lincoln, 816 New England Bldg., Cleveland, Ohio.
Ives, Valentine S., County Surveyor's Office, Cleveland, Ohio.
Jewett, Wm. C., 541 Ridgeway ave., Avondale, Cincinnati, Ohio.
Johnson, A. C., Trenton ave., Station D, Pittsburg, Pa.
Johnston, A. W., Hickox Bldg., Cleveland, Ohio.

Jones, Ed. H., 11 S. Water st., Cleveland, Ohio.
Jones, Harry R., 517 Sibley st., Cleveland, Ohio.
Jones, W. C., 57 Wade Bldg., Cleveland, Ohio.
Judson, C. A., Erie Co. Abstract Co., Sandusky, Ohio.
Kershaw, E. J., 31 Michigan st., Cleveland, Ohio.
Kimball, Hiram, Cleveland City Forge and Iron Co., Cleveland, Ohio.
King, J. A., 1325 Euclid ave., Cleveland, Ohio.
Kingsley, M. W., 354 Superior st., Cleveland, Ohio.
Kohlmetz, Geo. W., 181 Taylor st., Cleveland, Ohio.
Lander, Frank R., 321 Marcy ave., Cleveland, Ohio.
Lane, E. G., 77 Wade Bldg., Cleveland, Ohio.
Langley, Jno. W., Case School of App. Sc., Cleveland, Ohio.
Larned, J. B., 13 Isham Court, Cleveland, Ohio.
Leeper, J. B., Keystone Baggage Co., Fifty-first st., Pittsburg, Pa.
Lewis, R. T., Osborn Bldg., Cleveland, Ohio.
Lindenthal, G., 45 Cedar st., New York, N. Y.
Line, Francis, 117 Water st., Cleveland, Ohio.
Lucas, Geo. C., Bessemer ave., Cleveland, Ohio.
Lucas, H. M., 43 Kenwood st., Cleveland, Ohio.
Mabery, Prof. C. F., 57 Adelbert st., Cleveland, Ohio.
Marble, Henry D., 405 Bolton ave., Cleveland, Ohio.
Marani, V. G. F., 356 Superior st., Cleveland, Ohio.
McGeorge, John, 1404 New England Bldg., Cleveland, Ohio.
McIntyre, James, 136 Sawtelle ave., Cleveland, Ohio.
McLouth, Louis C., Central Manual Training School, Cedar ave., Cleveland, Ohio.
Metcalf, Frederick, 111 Elm st., Cleveland, Ohio.
Michelson, Prof. A. A., University of Chicago, Chicago, Ill.
Miller, Prof. Dayton C., Case School of App Sc., Cleveland, Ohio.
Miller, Walter, 808 Western Reserve Bldg., Cleveland, Ohio.
Mills, Edwin S., 802 Perry-Payne Bldg., Cleveland, Ohio.
Mitchell, A. E., 90 High st., Passaic, N. J.
Mordecai, A., 830 Garfield Bldg., Cleveland, Ohio.
Morley, Dr. E. W., Adelbert College, Cleveland, Ohio.
Morse, B. F., 36 Cheshire st., Cleveland, Ohio.
Naylor, E. W., Fiftieth st. and Lancaster ave., Philadelphia, Pa.
Neff, Frank H., 860 Doan st., Cleveland, Ohio.
Nelson, Harry S., New England Bldg., Cleveland, Ohio.
Oldham, Joseph R., 814 Perry-Payne Bldg., Cleveland, Ohio.
Oliver, John G., Case ave, and Hamilton st., Cleveland, Ohio.
Osborn, Frank C., The Osborn Bldg., Cleveland, Ohio.
Otis, Chas. A., Jr., 407 Perry-Payne Bldg., Cleveland, Ohio.
Otis, Wm. L., 255 Erie st., Cleveland, Ohio.
Paine, Chas., Tenafly, N. J.
Palmer, C. O., 32 Cedar ave., Cleveland, Ohio.
Parmley, Walter C., 19 Burt st., Cleveland, Ohio.
Paul, George, Cuyahoga Falls, Ohio.
Petterson, A. H., 699 Grove st., Columbus, Ohio.
Porter, A. H., Osborn Bldg., Cleveland, Ohio.
Prentiss, Francis F., 229 Euclid ave., Cleveland, Ohio.
Rawson, M. E., 762 Genesee ave., Cleveland, Ohio.
Raynal, Alfred H., 42 West Clinton st., Cleveland, Ohio.
Reed, Wm. E., 125 Fourth ave., Cleveland, Ohio.
Rice, W. P., 545 Society for Savings, Cleveland, Ohio.
Richards, Francis H., Phoenix Bank Bldg., Hartford, Conn.
Richardson, J. N., 262 Prospect st., Cleveland, Ohio.
Rider, Geo. S., 604 Century Bldg., Cleveland, Ohio.
Ritchie, James, Hickox Bldg., Cleveland, Ohio.
Rose, E. E., Norwalk Iron Wks. Co., South Norwalk, Conn.
Sawtelle, Edmund M., 1925 N st., N. W., Washington, D. C.
Sample, John H., 402 Society for Savings, Cleveland, Ohio.
Schmitt, J. G., 356 Superior st., Cleveland, Ohio.
Schroeder, Wm. E., Forest City Steel and Iron Co., Cleveland, Ohio.
Schulz, C. F., 354 Superior st., Cleveland, Ohio.

Searles, Wm. H., 625 Hickox Bldg., Cleveland, Ohio.
Short, Prof. S. H., 960 Prospect st., Cleveland, Ohio.
Skeels, Arthur A., 890 Denison ave., Cleveland, Ohio.
Smith, James A., 1 Front st., Cleveland, Ohio.
Smith, Col. Jared A., 185 Euclid ave., Cleveland, Ohio.
Smith, James J., 404 Erie st., Cleveland, Ohio.
Smythe, F. A., Lorain Foundry Co., Lorain, Ohio.
Sperry, Elmer A., 855 Case ave., Cleveland, Ohio.
Staley, Dr. Cady, 63 Adelbert st., Cleveland, Ohio.
St. John, R. H., 314 Seneca st., Cleveland, Ohio.
Stockwell, J. N., 1008 Case ave., Cleveland, Ohio.
Strong, C. H., 803 Cuyahoga Bldg., Cleveland, Ohio.
Strong, Harry B., 803 Cuyahoga Bldg., Cleveland, Ohio.
Swasey, Ambrose, 57 E. Prospect st., Cleveland, Ohio.
Thomas, Carl C., Globe Iron Wks. Co., Cleveland, Ohio.
Titcomb, George E., 23 La Grange st., Cleveland, Ohio.
Thompson, W. S., Broadway Passenger Station, Cleveland, Ohio.
Torrance, Wm. M., Osborn Bldg., Cleveland, Ohio.
Treat, Francis H., 2644 Euclid ave., Cleveland, Ohio.
Uebelacker, Chas. F., Kingston, N. Y.
Varney, J. D., 53 Public Square, Cleveland, Ohio.
Waitt, A. M., L. S. and M. S. Ry. Co. Bldg., Cleveland, Ohio.
Walker, John, 576 W. Adams st., Chicago, Ill.
Walker, W. J., 444 Crawford Road, Cleveland, Ohio.
Wallace, James C., 120 Viaduct st., Cleveland, Ohio.
Warner, W. R., 1722 Euclid ave., Cleveland, Ohio.
Watson, Wilbur J., Osborn Bldg., Cleveland, Ohio.
Webb, Robert L., 21 West Roy ave., Cleveland, Ohio.
Webster, C. E., So. Bethlehem, Pa.
Wellman, S. T., New England Bldg., Cleveland, Ohio.
West, Thos. D., Sharpsville, Pa.
White, Rollin H., 56 Hilburn ave., Cleveland, Ohio.
White, Windsor T., 124 Euclid ave., Cleveland, Ohio.
Willard, Joseph W., 1339 Willson ave., Cleveland, Ohio.
Wilson, Frank W., 156 Broadway, N. Y.
Wilson, Gen. J. M., War Department, Washington, D. C.
Wood, H. W. S., 763 Wilson ave., Cleveland, Ohio.
Wood, James, 163 Bolton ave., Cleveland, Ohio.
Wolverton, I. M., New Columbus Bridge Co., Columbus, Ohio.

FOREIGN.

Bright, Fred E., 145 Cannon st., E. C., London, Eng.

Engineers' Club of St. Louis.

Abbott, F. W., 620 Chestnut st., St. Louis, Mo.
Ashburner, Thos., 817 Security Bldg., St. Louis, Mo.
Baier, Julius, The Glockner, Colorado Springs, Col.
Baker, Vernon, 77 E. May st., St. Louis, Mo.
Barns, Wm. E., Equitable Bldg., St. Louis, Mo.
Bascome, Western R., 84 Broadway, Brooklyn, N. Y.
Barth, C. G. L., 54 Morningside ave., New York, N. Y.
Bausch, Frederick E., 2906 N. 21st St. Louis, Mo.
Bary, Mark, 1615 Missouri ave., St. Louis, Mo.
Beahan, W., 60 Forsyth st., Owego, Tioga co., N. Y.
Blaisdell, A. H., 1515 Lucas Place, St. Louis, Mo.
Borden, Albert, 2903 Gamble st., St. Louis, Mo.
Bouton, George I., 2909 Park ave., St. Louis, Mo.
Bouton, Wm., 2909 Park ave., St. Louis, Mo.
Boyd, Alfred, 4276 Cook ave., St. Louis, Mo.
Branch, Henry, 4314 Washington ave., St. Louis, Mo.

Branne, John S., Koken Iron Wks., Chonteau ave. and Manchester road, St. Louis, Mo.
Brenneke, W. G., 2605 S. Compton ave., St. Louis, Mo.
Brown, C. C., Bloomington, Ill.
Brown, C. I., 217 State st., Mankato, Minn.
Brown, W. S., 8328 S. Broadway, St. Louis, Mo.
Bryan, Chas. W., Edge Moor Bridge Wks., Wilmington, Del.
Bryan, Wm. H., I, Turner Bldg., St. Louis, Mo.
Bruner, P. M., Turner Bldg., St. Louis, Mo.
Burgess, Robt., G., C. and S. F. Ry., Galveston, Texas.
Burnet, Geo., 4415 Washington ave., St. Louis, Mo.
Butler, L. P., 1515 Lucas Place, St. Louis, Mo.
Caldwell, W. A., Jr., 4600 Maryland ave., St. Louis.
Carr, L. H., 143 Liberty st., New York, N. Y.
Chaplie, Jas. M., 5240 Minerva ave., St. Louis, Mo.
Chaplin, W. S., Washington University, St. Louis, Mo.
Chassaing, Chas. W., 1762 Missouri ave., St. Louis, Mo.
Childs, Oliver W., 2301 S. Seventh st., St. Louis, Mo.
Chollar, B. E., 413 N. 11th st., St. Louis, Mo.
Clark, C. W., Webster Groves, Mo.
Colby, B. H., City Hall, St. Louis, Mo.
Colnon, R. S., 118 Laclede Bldg., St. Louis, Mo.
Comber, W. G., 2732 Pine st., St. Louis, Mo.
Connor, E. H., Fullerton Bldg., St. Louis, Mo.
Cook, Abr., 4500 N. 2d st., St. Louis, Mo.
Crecelius, S. F., 1515 Locust st., St. Louis, Mo.
Crosby, B. L., 1213 Charles st., St. Joseph, Mo.
Crow, B. F., Cairo, Ill.
Dean, John, 4852 Maffit ave., St. Louis, Mo.
Delafield, C. E., American Central Bldg., St. Louis, Mo.
Desloge, John M., Desloge, Mo.
Dickens, A. W., 601 Baden ave., St. Louis, Mo.
Dun, James, Topeka, Kan.
Dunaway, Horace, 1515 Locust st., St. Louis, Mo.
Dziatzko, Leo C., 2912 Ellendale ave., St. Louis.
Farrham, S. W., 2943 Thomas st., St. Louis, Mo.
Ferguson, O. W., 2128 McCausland ave., St. Louis, Mo.
Fish, E. R., 2328 Arkansas ave., St. Louis, Mo.
Fischer, L. D., U. S. S. "Buffalo," Philippine Islands.
Fischer, C. O., 3140 Russell ave., St. Louis, Mo.
Fisher, Geo. W., 2d and Carr sts., St. Louis, Mo.
Fisher, Samuel B., 406 Wainwright Bldg., St. Louis, Mo.
Flad, Edward 118 Laclede Bldg., St. Louis, Mo.
Foster, C. F., 1407 Manhattan Bldg., Chicago, Ill.
Frederick, E. P., 4044 Delmar ave., St. Louis, Mo.
Freeman, S. E., 720 N. 4th st., St. Louis, Mo.
French, A. W., National Lead Co., Atlantic Branch, Brooklyn, N. Y.
French, Geo. H., 2732 Pine st., St. Louis, Mo.
Garrels, W. L., 4531 W. Pine st., St. Louis, Mo.
Gayler, Carl, City Hall, St. Louis, Mo.
Gould, Wm. T., Waco, Texas.
Graves, W. N., 2813 Lafayette ave., St. Louis, Mo.
Groneman, Henry, 2719 Stoddard st., St. Louis Mo.
Guinn, John B., Box 603, Aspen, Col.
Harrington, F. F., 406 Locust st., Philadelphia, Pa.
Hammond, A. J., Terre Haute, Ind.
Hawkes, C. W., 221 E. Jackson st., Springfield, Ill.
Hazzard, A. B., 615 N. 2d st., St. Louis, Mo.
Hendricks, V. K., 714 Mulberry st., Terre Haute, Ind.
Hermann, Edw. A., 505 N. Spring ave., St. Louis, Mo.
Hill, John, Wainwright Bldg., St. Louis, Mo.
Hofmann, Alvin, 8328 N. Broadway, St. Louis, Mo.
Holman, M. L., 3744 Finney ave., St. Louis, Mo.
Howe, Malverd A., Terre Haute, Ind.
Hubbard, A. W., 706 Oriole Bldg., St. Louis, Mo.
Humphrey, H. H., Room I, Turner Bldg., St. Louis, Mo.
Hunicke, Wm. R., Motive Power Dept. Mexican Central Ry., City of Mexico, Mexico.

Hutchinson, Cary T., 71 Broadway, New York, N. Y.
Ingoldsby, F. S., 608 Chemical Bldg., St. Louis, Mo.
Jennings, J G., City Hall, St. Louis, Mo.
Jewett, E. C., Fundicion No. 2, Monterey, Mexico.
Johnson, A. L., 606 Century Bldg., St. Louis, Mo.
Johnson, J. B., Washington University, St. Louis, Mo.
Jolley, E. J., 4877 Fountain ave., St. Louis, Mo.
Jones, C. E., Manual Training School, St. Louis, Mo.
Judson, J. N., Box 957, New York, N. Y.
Kimball, Clinton, American Steel Fdy. Co., Granite City, Ill.
Kinealy, J. H., Washington University, St. Louis, Mo.
Krutzsch, Herman, 3863 Cleveland ave., St. Louis, Mo.
Latta, G. W., Motive Power Dept. Mexican Central Ry., City of Mexico, Mexico.
Laird, John A., 8328 N. Broadway, St. Louis, Mo.
Layman, Waldo A., 2017 Locust st., St. Louis, Mo.
Leighton, George B., Rialto Bldg., St. Louis, Mo.
Levy, Will., Odd Fellows' Bldg., St. Louis, Mo.
Lichter, John J., Jr., 5305 Virginia ave., St. Louis, Mo.
Libby, E. D., Custom House, St. Louis, Mo.
Leonard, E. F., Springfield, Ill.
Lucke, Chas. E., 708 Locust st., St. Louis, Mo.
Maltby, F. B., Box 217, Memphis, Tenn.
McCulloch, Richard, 2401 N. Spring ave., St. Louis, Mo.
McMath, R. E., City Hall, St. Louis, Mo.
McMath, Thos. B., 5428 Clemens ave., St. Louis, Mo.
McMillin, Emerson, 40 Wall st., New York, N. Y.
McRae, A. L., Oriel Bldg., St. Louis, Mo.
Meier, E. D., Room 706, Bank of Commerce Bldg., St. Louis, Mo.
Meinholtz, H. C., 421 Olive st., St. Louis, Mo.
Melcher, C. W., 1515 Old Colony Bldg., Chicago, Ill.
Mersereau, C. V., 77 E. May st., St. Louis, Mo.
Miller, T. D., 261 Main st., Dallas, Texas.
Milner, A. N. City Hall, St. Louis, Mo.
Mitchell, C. D., 77 E. May st., St. Louis, Mo.
Mitchell, M. L., 1220 Armstrong ave., St. Louis, Mo.
Mitchell, W. S., Custom House, St. Louis, Mo.
Mitchell F. S., 15 Wall st., New York, N. Y.
Monell, J. T., Flat River, St. Francois co., Mo.
Montgomery G. S., 808 Bank of Commerce Bldg., St. Louis, Mo.
Moore, Robt., 119 Laclede Bldg., St. Louis, Mo.
Moore, Philip N., 121 Laclede Bldg., St. Louis, Mo.
Moore, Wm. H., 4224 John ave., St. Louis, Mo.
Morey, Richard, 716 New York Life Bldg., Kansas City, Mo.
Moulton, Julius, City Hall, St. Louis, Mo.
Mueller, John H., 441 North st., Baltimore, Md.
Mysenberg, T. A., American Central Bldg., St. Louis, Mo.
Nicholson, Frank, 504 5th ave., New York, N. Y.
Neff, W. A., Jr., 860 Doan st., Cleveland, Ohio.
Nipher, F. E., Washington University, St. Louis, Mo.
Ockerson, J. A., 2732 Pine st., St. Louis, Mo.
Overpeck, O. E., 77 E. May st., St. Louis, Mo.
O'Reilly, A. J., City Hall, St. Louis, Mo.
Parker, E. C., 2012 Oregon ave., St. Louis, Mo.
Parker, Lemon, 3413 Oak Hill ave., St. Louis, Mo.
Parker, Russell, 417 Pine st., St. Louis, Mo.
Parker, Charles M., 606 Union Trust Bldg., St. Louis, Mo.
Pegram, Geo. H., 195 Broadway, New York, N. Y.
Perkins, N. W., Jr., 4446 Page ave., St. Louis, Mo.
Pfeifer, H. J 208 Union Station, St. Louis, Mo.
Pitzman, Julius, 615 Chestnut st., St. Louis, Mo.
Pond, Frank, 506 Chemical Bldg., St. Louis, Mo.
Porter, Jos. F., Alton, Ills.
Poss, Victor H., U. S. Engineer's Office, St. Louis, Mo.
Potter, W. B., 1227 Spruce st., St. Louis, Mo.

Rauschenbach, A., 1433 Dodier st., St. Louis, Mo.
Reel, C. G., Station R, Kingston, N. Y.
Reber, H. L., Rialto Bldg., St. Louis, Mo.
Reeves, Wm. H., 317 N. 9th st., St. Louis, Mo.
Roper, D. W., 1908 Locust st., St. Louis, Mo.
Russell, S. Bent, 77 E. May st., St. Louis, Mo.
Ruckert, Louis, 3023 Shenandoah st., St. Louis, Mo.
Sanders, J. D., 290 Boulevard, West, Detroit, Mich.
Saxton, E., 1244 11th st., N. W., Washington. D. C.
Schaub, J. W., 1731 Monadnock Blk., Chicago, Ill.
Schaumleffel, P. W., 2329 Whittemore Place, St. Louis, Mo.
Schlosser, F. G., 411 N. 11th st., St. Louis, Mo.
Scott, Wm. F., Koken Iron Wks., St. Louis, Mo.
Schramm, O. H., 1222 Union ave., Kansas City, Mo.
Schmitz, Otto, 2114 S. Compton ave., St. Louis, Mo.
Schwedtmann, Ferd., 2017 Locust st., St. Louis, Mo.
Seddon, J. A., 1515 Lucas Place, St. Louis, Mo.
Sherman, W. J., 613 Nasby Bldg., Toledo, Ohio.
Siebert, A., 14934 Columbia ave., St. Louis, Mo.
Smith, Bathurst, Custom House, Sioux City, Iowa.
Sneddon, J. P., Monadnock Blk., Chicago, Ill.
Spencer, E. J., 24 Laclede Bldg., St. Louis, Mo.
Stolberg, E. C., Room I, Turner Bldg., St. Louis, Mo.
Stuart, A. A., 1 Broadway, New York.
Sykes, H. H., Telephone Bldg., St. Louis, Mo.
Sypher, A. J., Patterson, St. Mary Parish, Louisiana.
Taussig, H. B., 224 Wainwright Bldg., St. Louis.
Taylor, J. W., Union Station, St. Louis, Mo.
Thatcher, Arthur, 4109 Washington ave., St. Louis, Mo.
Thul, J. P., 3632 S. Broadway, St. Louis, Mo.
Tidemann, H. G., 1726 Mississippi ave., St. Louis, Mo.
Trepp, Samuel, 522 Theresa ave., St. Louis, Mo.
Tripp, Chas. A., 1615 Missouri ave., St. Louis, Mo.
Turner, O. H. B., 1609 Semple ave., St. Louis, Mo.
Vail, J. A., Webster Groves, Mo.
Van Sant, R. L., 609 Commercial Bldg., St. Louis, Mo.
Varrellman, C., City Hall, St. Louis, Mo.
Walker, I. O., 1231 S. 6th st., Paducah, Ky.
Wall, Ed. E., City Hall, St. Louis, Mo.
Wagner, H. A., 4125 Delmar ave., St. Louis, Mo.
Wangler, J. F., 1535 N. 9th st., St. Louis, Mo.
Warren, B., T. P. and W. Ry., Peoria, Ill.
Wheeler, H. A., 3124 Locust st., St. Louis, Mo.
Williams, W. S., 2732 Pine st., St. Louis, Mo.
Winslow, Arthur, Missouri, Kansas and Texas Trust Co., Kansas City, Mo.
Wilson, H. S., Novelty and Mfg. Co., Tenth and Walnut sts., St. Louis, Mo.
Wise, Wm., City Hall, St. Louis, Mo.
Woermann, J. W., Sheffield, Ill.
Womeldorf, C. F., 10740 Columbia Bottom road, St. Louis, Mo.
Woodward, E. K., Box 271, Peru, Ind.
Zeller, Albert H., 1000 Fullerton Bldg., St. Louis, Mo.

FOREIGN.

Olshausen, Geo. R., Berlin, N. Artillerie st., 13, Germany.
Yeatman, Pope, P. O. Box 67, Johannesburg, South Africa.

Engineers' Club of Minneapolis.

Brooks, Prof. Morgan, University of Nebraska, Lincoln, Neb.
Cappelen, F. W., 2129 S. Girard ave., Minneapolis, Minn.
Coe, A. B., 825 Belmont ave., Seattle, Wash.
Dealing, W. F., City Hall, Minneapolis, Minn.

Durham, B. H., 607 E. Franklin ave., Minneapolis, Minn.
Dutton, E. R., 3340 Pleasant ave., Minneapolis, Minn.
Egan, J. E., 255 Hennepin ave., Minneapolis, Minn.
Fanning, R. B., 602 Kasota Bldg., Minneapolis, Minn.
Gillette, Minneapolis, Minn.
Graber, Albert, 141 N. E. Fifth ave., Minneapolis, Minn.
Hoag, Prof. W. R., University of Minnesota, Minneapolis, Minn.
Howe, I. E., 2643 S. Humboldt ave., Minneapolis, Minn.
Ilstrup, Carl, City Hall, Minneapolis, Minn.
Loe, E. H., 311 S. Third st., Minneapolis, Minn.
Lund, N. J., City Hall, Minneapolis, Minn.
Nexsen, Elbert, 1620 S. E. Fourth st., Minneapolis, Minn.
Pillsbury, Chas. L., City Hall, Minneapolis, Minn.
Redfield, W. W., 1817 Portland ave., Minneapolis, Minn.
Shepardson, Prof. G. D., University of Minnesota, Minneapolis, Minn.
Smith, Prof. Harry E., University of Minnesota, Minneapolis, Minn.
Stack, W. E., Camden Place, Minneapolis, Minn.
Stoopes, W. E., 3343 S. Fourth ave., Minneapolis, Minn.
Sublette, Geo. W., City Hall, Minneapolis, Minn.
Webster, J. S., 429 S. Sixth st., Minneapolis, Minn.
Woolf, E. J., 912 Guaranty Loan Bldg., Minneapolis, Minn.

Montana Society of Engineers.

HONORARY MEMBERS.

Beckler, Elbridge H., 1339 Wilton ave., Chicago, Ill.
Dodge, Joseph T., 346 W. Washington ave., Madison, Wis.
Haven, William A., Room 10, Erie R. R. Depot, Buffalo, N. Y.
McHenry, Edwin H., St. Paul, Minn.

ACTIVE MEMBERS.

Allen, Charles M., Box 515, Missoula, Mont.
Baker, Thomas T., Butte, Mont.
Barker, Samuel, Jr., Butte, Mont.
Bayliss, Rawlinson T., 54 Old Broad st., London, E. C., England.
Beach, Frank, Las Animas, Col.
Bickel, Paul S., Helena, Mont.
Blackford, Francis W., 48 E. Broadway, Butte, Mont.
Bond, Benjamin, Dillon, Mont.
Booth, Charles F., Butte, Mont.
Braden, William, Box 136, Helena, Mont.
Bradford, Donald, Helena, Mont.
Breen, James, Northport, Wash.
Cantine, Edward I., Helena, Mont.
Carroll, Eugene, Butte, Mont.
Christian, August, Box 169, Butte, Mont.
Clark, Charles W., Butte, Mont.
Clark, Harry P., Winston, Mont.
Clark, Joseph K., Butte, Mont.
Clark, William A., Butte, Mont.
Crookes, Spencer H., Livingston, Mont.
Cumming, Adelbert E., Harlem, Mont.
Davis, Henry B., Deer Lodge, Mont.
Dean, Andrew L., Trail, British Columbia.
Dewar, Charles A., Billings, Mont.
Donovan, William E., Silver Bow Block, Butte, Mont.
Donovan, John J., Fairhaven, Wash.
Dunshee, Bertrane H., Box 1011, Butte, Mont.
Ellison, James H., No. 3237 Stevens ave., Minneapolis, Minn.
Fitch, Howard A., Lewisohn Block, Butte, Mont.
Fortiner, Walter S., Helena, Mont.
French, John, Great Falls, Mont.
Gillie, John, Butte, Mont.
Gillies, Donald B., Butte, Mont.
Goodale, Charles W., Great Falls, Mont.
Grant, Robert D., Butte, Mont.
Griswold, Leon S., 238 Boston st., Dorchester, Mass.
Gutelius, Fred P., Trail, British Columbia.
Hand, Carlton H., Butte, Mont.
Harper, Joseph H., Butte, Mont.
Harrison, William H., 48 E. Broadway, Butte, Mont.
Hebgen, Max, Butte, Mont.
Heinze, F. August, Butte, Mont.
Heller, Daniel E., 108 N. Montana st., Butte, Mont.

Henley, James H., Helena, Mont.
Herron, David A., Marysville, Mont.
Herron, John, Telluride, Col.
Hollinshead, Jas. S. B., Butte, Mont.
Horn, Henry J., Jr., Livingston, Mont.
Hovey, Albert S., Helena, Mont.
Jaqueth, Abram L., Kalispell, Mont.
Keerl, James S., Box 374, Helena, Mont.
Kelley, Walter S., Elkhorn, Mont.
Kerr, Guy M., York, Mont.
Kerr, James H., Hotel Ruliff, Glens Falls, N. Y.
Ketchum, Milo S., Box 380, Houghton, Mich.
King, Ernest W., Gilt Edge, Mont.
Kinney, Edward C., Manhattan, Mont.
Klepetko, Frank, Great Falls, Mont.
Leonard, Frank M., Libby, Mont.
MacDonald, Malcolm L., Butte, Mont.
McFarlane, James, Butte, Mont.
MacGinniss, John, Box 427, Butte, Mont.
McArthur, Robert A., Box 757, Butte, Mont.
McLeod, John D., Helena, Mont.
McNeill, Edward R., Boulder Valley, Mont.
McRae, Finlay, Helena, Mont.
Mahon, Archibald W., Glasgow, Mont.
Mason, Carlisle, Box 272, Butte, Mont.
Metlen, George R., Dillon, Mont.
Morris, Albert A., Billings, Mont.
Moulthrop, George E., P. O. Box 674, Butte, Mont.
Mumbrue, Daniel P., Helena, Mont.
Munroe, William, Great Falls, Mont.
Page, James M., Twin Bridges, Mont.
Palmer, Charles H., Butte, Mont.
Parker, Maurice S., "The Reed," Ogden, Utah.
Parks, John R., Helena, Mont.
Patterson, Henry M., Butte, Mont.
Patterson, John C., Anaconda, Mont.
Reed, Melville E., Wellington, Wash.
Reeder, George K., Craig, Mont.
Repath, Charles H., Butte, Mont.
Ripley, Theron M., Serg't Co. L., 1st Montana V. I., Manila, Philippine Islands.
Robinson, George H., 876 Walker Bank Bldg., Salt Lake City, Utah.
Scheuch, Frederick C., Missoula, Mont.
Schumacher, Adam J., 1225 E. Second st., Butte, Mont.
Scotten, Frank, Box 582, Great Falls, Mont.
Seligman, Albert J., Helena, Mont.
Shaw, Wm. Trautwine, 200 Pike st., Seattle, Wash.
Sherman, Frederic W., Quartzburg, Idaho.
Sizer, Frank L., Helena, Mont.
Smith, Charles P., 622 Maryland ave., Butte, Mont.
Smith, Forrest J., Helena, Mont.
Smith, Frank M., Smelter P. O., Great Falls, Mont.
Swearingen, Clar. W., Great Falls, Mont.
Taylor, Frederic J., Tacoma, Wash.
Thorpe, Clayton M., Bozeman, Mont.
Turner, Harry W., Butte, Mont.
Vail, Charles D., Box 561, Butte, Mont.
Wade, John W., Helena, Mont.
Warwick, Arthur W., Stillwater, Minn.
Weed, Walter H., Washington, D. C.
Weir, Thomas, Box 57, Salt Lake City, Utah.
Wheeler, Harry V., Long Beach, Cal.
Whitcomb, Adelbert F., St. Paul, Minn.
White, Robeson T., 208 W. Copper st., Butte, Mont.
Whitten, Benjamin D., Box 56, Great Falls, Mont.
Whyte, Frederick W. C., Belt, Mont.
Wickes, George T., Helena, Mont.
Williams, William H., Bozeman, Mont.
Wilson, Elliott H., Butte, Mont.
Word, William F., Box 64, Marysville, Mont.
Young, John W., Chicago, Ill.

Civil Engineers' Society of St. Paul.

Alderman, C. A., Eau Claire, Wis.
Annan, C. L., City Engineer's Dept., St. Paul, Minn.
Armstrong, J. H., 504 Globe Bldg., St. Paul, Minn.
Blodgett, John, East Side House, 76th st. and East River New York, N. Y.
Clark, H. E., Army Bldg., St. Paul, Minn.

Claussen, O. L., 203 Newspaper Row, St. Paul, Minn.
Crosby, Oliver, St. Paul, Minn.
Crocker, H. S., City Hall, Denver, Col.
Curtin, David, 31st st. and Blaisdell ave., Minneapolis, Minn.
Curtis, W. W., 549 Marquette Bldg., Chicago, Ill.
Darling, W. L., N. P. Railway Bldg., St. Paul, Minn.
Darling, F. S., N. P. Railway Bldg., St. Paul, Minn.
Du Shane, Jas. D., Army Bldg., St. Paul, Minn.
Elder, Robt., Fairbanks, Morse & Co., St. Paul, Minn.
Elmer, H. N., 1114 Monadnock Bldg., Chicago, Ill.
Estabrook, J. D., 699 Lincoln ave., St. Paul, Minn.
Fernström, H., Chicago Great Western Ry. Co., St. Paul, Minn.
Forbes, Chas. A., Room 11, Court Block, St. Paul, Minn.
Freyhold, Felix, 236 First st., S. E., Washington, D. C.
Harrison, H. H., Stillwater, Minn.
Hedges, S. H., Washington Heights P. O., Chicago, Ill.
Herzog, Robt., Great Northern Ry. Co., St. Paul, Minn.
Heuston, Geo. Z., Winona, Minn.
Hilgard, K. E., 18 Steinweiss Strasse, Zürich V. Switzerland.
Hogeland, Albert H., Great Northern Ry. Co., St. Paul, Minn.
Horton, H. E., Chicago Bridge and Iron Co., Chicago, Ill.
Hunt, C. A., Minot, N. D.
Jackson, Alfred, Spokane, Wash.
Johnson, Archibald, 418 Globe Bldg., St. Paul, Minn.
Johnson, C. W., C., St. P., M. & O. Ry. Co., St. Paul, Minn.
Lehman, K L., 88 Dexter Bldg., Chicago, Ill.
Loweth, C. F., 94 E. Fourth st., St. Paul, Minn.
Lyon, Tracy, Chicago Great Western Ry. Co., St. Paul, Minn.
McCoy, F. W., Great Northern Ry. Co., St. Paul, Minn.
Miller, Hew, Room 10, Floor 11, 100 Broadway, New York, N. Y.
Miller, N. D., Great Northern Ry. Co., St. Paul, Minn.
Morris, C. J. A., 904 Globe Bldg., St. Paul, Minn.
Münster, A. W., City Engineer's Department, St. Paul, Minn.
Powell, Capt. A. O., 418 Globe Bldg., St. Paul, Minn.
Rockwell, Samuel, M. S. Div., L. S. & M. S. R. R. Co., Toledo, O.
Rundlett, L. W., St. Paul, Minn.
Smith, W. C., Brainerd and Northern Minn. Ry. Co., Brainerd, Minn.
Somers, W. A., Room 33, Metropolitan Opera House, St. Paul, Minn.
Starkey, A. R., Water Works, St. Paul, Minn.
Stevens, H. E., 530 Grand ave., St. Paul, Minn.
Swenson, H. A., 638 Endicott Bldg., St. Paul, Minn.
Toltz, Max, Great Northern Ry. Co., St. Paul, Minn.
Truesdell, W. A., St. Paul Union Stockyards Co., South St. Paul, Minn.
Wilgus, W. J., Room 48, Grand Central Station, New York, N. Y.
Williamson, Sydney B., U. S. Muscle Shoals Canal, Florence, Ala.
Wilson, Geo. L., City Engineer's Department, St. Paul, Minn.
Winslow, C. A., City Engineer's Department, St. Paul, Minn.
Woodman, E. E., C., St. P., M. & O. Ry. Co., St. Paul, Minn.

Technical Society of the Pacific Coast.

Allardt, Geo. F., 420 California st., San Francisco, Cal.
Barth, Hermann, 601 California st., San Francisco, Cal.
Bassell, Burr, Room 524, Stimson Blk., Los Angeles, Cal.
Behr, H. C., 320 Sansome st., Room 56, San Francisco, Cal.
Boyd, Joseph C., Sacramento, Cal.
Bowers, A. B., Great Northern Hotel, Chicago, Ill.
Brandegee, T. S., Box 684, San Diego, Cal.
Brodie, Alex. O., Prescott, Arizona.
Browne, Ross E., Nevada Block, San Francisco, Cal.
Buckman, O. H., Napa City, Cal.

Brooks, T. W., 19 Beale st., San Francisco, Cal.
Blood, Geo. D., 2526 Durant ave., Berkeley, Cal.
Chodzko, A. E., 106 Market st., San Francisco, Cal.
Congdon, Chas. H., Bakersfield, Kern county, Cal.
Cory, Prof. Clarence, University of California, Berkeley, Cal.
Crockett, J. B., 415 Post st., San Francisco, Cal.
Curtis, W. G., Montgomery and Market sts., San Francisco, Cal.
Carssow, F. H., 117 Walnut st., Johnstown, Pa.
Dickie, Geo. W., Union Iron Works, San Francisco, Cal.
Doble, Wm. A., S. W. cor. Howard and Fremond sts., San Francisco, Cal.
Dow, Geo. E., 114 Beale st., San Francisco, Cal.
Downs, Walter E., Sutter Creek, Cal.
Dunn, Russell L., Larkspur, Cal.
Eaton, Fred, Burdick Block, Los Angeles, Cal.
Edinger, F. S., Bowditch st., Berkeley, Cal.
d'Erlach, A., 3821 20th st., San Francisco, Cal.
Evans, Geo. H., Oroville, Cal.
Falkenau, Louis, 434 California st., San Francisco, Cal.
Ferris, J. W., 320 Sansome st., San Francisco, Cal.
Forsyth, Robert, Union Iron Works, San Francisco, Cal.
Gates, H. D., 311 Lyon st., San Francisco, Cal.
Gray, John W., 923 Linden st., Oakland, Cal.
Grunsky, C. E., 530 California st., San Francisco, Cal.
Gutzkow, Frederick, 28 Columbia Square, San Francisco, Cal.
Haas, Edward F., 320 Sansom st., San Francisco, Cal.
Hall, C. I., 21 Bernal ave., San Francisco, Cal.
Hall, Wm. Ham, Johannesburg, South African Republic.
Hare, Lou G., Salinas, Monterey county, Cal.
Hasson, W. F. C., 310 Pine st., San Francisco, Cal.
Herrmann, Chas., 24 Martin's Block, San Jose, Cal.
Hesse, Prof. Fred. G., P. O. Box 452, Oakland, Cal.
Henny, D. C., 204 Front st., San Francisco, Cal.
Hewitt, Edward T., 619 Capp st., San Francisco, Cal.
Hoffman, Chas. F., Blagowestschensk, Siberia, Russia.
Harmon, Dana, Graniteville, Nevada county, Cal.
Hopps, John H., 2613 Union st., San Francisco, Cal.
Hughes, D. E., Eureka, Cal.
Jackson, Byron, 625 Sixth st., San Francisco, Cal.
Jones, Edward C., 415 Post st., San Francisco, Cal.
Kower, Prof. Hermann, cor. Prospect and Lewis sts., E. Oakland, Cal.
Kellogg, H. Clay, Santa Anna, Cal.
Lacy, B. T., 615 Chestnut st., San Francisco, Cal.
Le Conte, L. J., P. O. Box 492, Oakland, Cal.
Lietz, Adolph, 422 Sacramento st., San Francisco, Cal.
Manson, Marsden, Sacramento, Cal.
Marx, Prof. Chas. D., Leland Stanford, Jr., University, Palo Alto, Cal.
Masson, R. S., Mills Building, San Francisco, Cal.
Medina, Frank P., 534 Market st., San Francisco, Cal.
Meese, Constant, 129 Fremont st., San Francisco, Cal.
Meyer, Hermann, 1130 Eddy st., San Francisco, Cal.
Molera, E. J., 606 Clay st., San Francisco, Cal.
Mendell, Col. Geo. H., 530 California st., San Francisco, Cal.
Merrill, E. H., 421 Market st., San Francisco, Cal.
Moore, R. S., Risdon Iron Works, San Francisco, Cal.
Noble, Patrick, Pacific Rolling Mills, San Francisco, Cal.
Nissley, Lincoln, Box 195, Los Angeles, Cal.
O'Shaughnessy, M. M., 225 Crocker Bldg., San Francisco, Cal.
Percy, G. W., 532 Market st., San Francisco, Cal.
Perry, Homer, 714 Hampshire st., San Francisco, Cal.
Power, Harold T., Michigan Bluff, California.
Power, Geo. C., San Buenaventura, Ventura county, Cal.
Pioda, Chas. L., Salinas, Cal.
Quinan, Wm. R., Pinole, Contra Costa county, Cal.
Randall, Prof. H. I., University of California, Berkeley, Cal.
Ransom, Tom W., Room 611, 330 Market st., San Francisco, Cal.

Reid, Jas. W., Room 700, Spreckles' Bldg., 927 Market st., San Francisco, Cal.
Ridley, A. E. Brooks, Parrott Bldg., 5th floor, San Francisco, Cal.
Richards, John, 22 California st., San Francisco, Cal.
Rossow, Ernest F., Vallejo, Solano county, Cal.
Schild, Geo. F., Vallejo, Solano county, Cal.
Sala, Jos. C., 429 Montgomery st., San Francisco, Cal.
Sanborn, A. H., 1713 McAllister st., San Francisco, Cal.
Schierholz, Salinas, Cal.
McNicoll, A. J., 122 Main st., San Francisco, Cal.
Schindler, A. D., Yosemite Hotel, Stockton, Cal.
Schulze, Henry A., 94 Flood Bldg., San Francisco, Cal.
Schuyler, J. D., 524 Stimson Blk., Third and Spring sts., Los Angeles, Cal.
Smith, Wm. P., 1017 Monadnock Bldg., Chicago, Ill.
Soule, Prof. Frank, University of California, Berkeley, Cal.
Spiers, James, Fulton Iron Works, San Francisco, Cal.
Storey, W. B., Jr., 321 Market st., San Francisco, Cal.
Stut, J. Ch. H., 217 Sansome st., San Francisco, Cal.
Thompson, Lawrence, 530 California st., San Francisco, Cal.
Taylor, Leon H., Golconda, Nevada.
Tower, Morton L., Marshfield, Ore.
Uhlig, Carl, Ferry Bldg., San Francisco, Cal.
Vail, R. M., Room 41, Court House, San Diego, Cal.
Vischer, Hubert, Flood Bldg., San Francisco, Cal.
von Geldern, Otto, 1513 Vallejo st., San Francisco, Cal.
Waggoner, W. W., Nevada City, Cal.
Wagoner, Luther, Safe Deposit Bldg., San Francisco, Cal.
Wallace, John H., 4 Montgomery st., San Francisco, Cal.
Wing, Prof. Chas. B., Leland Stanford, Jr., University, Palo Alto, Cal.
Wood, Fred W., cor Sixth st. and Central ave., Los Angeles, Cal.

JUNIOR MEMBERS.

Henderson, E. T., 602 N. Sutter st., Stockton, Cal.
Hirst, Harry H., 2430 Dwight Way, Berkeley, Cal.
Morrow, J. F., Kelton, Utah.
Hunt, Loren E., University of California, Berkeley, Cal.

ASSOCIATES.

Behr, Dr. H. H., Academy of Sciences, San Francisco, Cal.
Bell, Newton M., 109 California st., San Francisco, Cal.
Irving, Samuel C., 116 Battery st., San Francisco, Cal.
McBean, P. McG., 1358 Market st., San Francisco, Cal.
McCone, Alex. J., Fulton Foundry, Virginia City, Nevada.
Schild, Edward T., 1911 Green st., San Francisco, Cal.
Denio, O. H. M., Vallejo, Cal.
Greub, Adolf, 422 Sacramento st., San Francisco, Cal.

FOREIGN MEMBERS.

Capuccio, Mario, Piazza Statuto 15, Turin, Italy.
Hellmann, Fred'k, Johannesburg, South African Republic.
Kluegel, C. H., P. O. Box 98, Honolulu, Hawaii.
Morse, F. B., 7 Calle de los Flores, No. 1, Mexico, Mexico.
Turner, Lieut. F. C., 2d Regt. U. S. Vol. Eng., Honolulu, Hawaii.
Walker, J. S., Perth, West Australia.
Wepfer, G. W., Box 2088, Johannesburg, South African Republic.

Detroit Engineering Society.

Allen, John R., 226 S. Ingalls st., Ann Arbor, Mich.
Allor, Elmer L., 710 Union Trust Bldg., Detroit, Mich.
Ames, Joseph H., Michigan-Peninsular Car Co., Detroit, Mich.
Ashwell, William H., 24-25 Bennett Bldg., Detroit, Mich.
Atwater, Almon B., 26 Alexandrine ave., Detroit, Mich.
Bigler, F. S., Michigan Bolt and Nut Works, Detroit, Mich.

Bothfeld, Charles C., 34 Home Bank Bldg., Detroit, Mich.
Bridge, Henry, 166 Alexandrine ave., W., Detroit, Mich.
Brinkerhoff, W. E., Detroit Bridge and Iron Works, Detroit, Mich.
Burton, Charles F., 12 Hodges Blk., Detroit, Mich.
Calder, Charles B., Dry Dock Eng. Works, Detroit, Mich.
Campau, M. Woolsey, 1112 Union Trust Bldg., Detroit, Mich.
Coffin, Charles L., 35 Medbury ave., Detroit, Mich.
Colburn, Burnham Standish, Detroit Bridge and Iron Works, Detroit, Mich.
Colby, Archie L., Detroit Bridge and Iron Works, Detroit, Mich.
Conant, William S., 36 Moffat Blk., Detroit, Mich.
Cooley, Mortimer E., 727 S. State st., Ann Arbor, Mich.
Courtis, William Munroe, 412 Hammond Bldg., Detroit, Mich.
Danziger, Jacob C., 927 Chamber of Commerce Bldg., Detroit, Mich.
Davis, Joseph Baker, 731 S. Ingals st., Ann Arbor, Mich.
Demrick, Almon H., 18 John R. st., Detroit, Mich.
Denison, Charles S., P. O. Box 174, Ann Arbor, Mich.
Dierkes, Anthony F., Detroit Water Office, Detroit, Mich.
Dixon, Charles Y., Amherstburg, Ontario, Canada.
Douglas, Benjamin, Michigan Central R. R., M. C. R. R. Depot, Detroit, Mich.
Dow, Alexander, Edison Bldg., cor. State st. and Washington ave., Detroit, Mich.
Duncan, W. J., Michigan Central R. R., M. C. R. R. Depot, Detroit, Mich.
Dunlap, Frank M., 57 Selden ave., Detroit, Mich.
Du Pont, Antoine B., 12 Woodward ave., Detroit, Mich.
Farmer, Thomas, Jr., 12 Woodward ave., Detroit, Mich.
Fenkell, George H., Detroit Water Office, Detroit, Mich.
Field, Henry George, 1203-4 Majestic Bldg., Detroit, Mich.
Folger, William M., Navy Department, Washington, D. C.
Gerhauser, William, 925 Chamber of Commerce Bldg., Detroit, Mich.
Goldmark, Henry, 34 Congress st., W., Detroit, Mich.
Green, A. H., Jr., Solvay Process Co., Detroit, Mich.
Greene, Albert E., Detroit Bridge and Iron Works, Detroit, Mich.
Greene, Charles E., 415 E. William st., Ann Arbor, Mich.
Hanford, Herbert O., Detroit Water Office, Detroit, Mich.
Haskell, E. E., Telephone Bldg., Detroit, Mich.
Hawks, James D., Union Trust Bldg., Detroit, Mich.
Hinchman, Theodore H., Jr., 1203-4 Majestic Bldg., Detroit, Mich.
Hitchcock, Dwight A., 1443 Majestic Bldg., Detroit, Mich.
Hodge, Harry S., 320 E. Atwater st., Detroit, Mich.
Hodges, Frederick W., Detroit Plant American Radiator Co., Detroit, Mich.
Hubbell, Clarence W., 232 Jefferson ave., Detroit, Mich.
Keep, William J., The Michigan Stove Co., Detroit, Mich.
Kiefer, Arthur E., Detroit Edge Tool Works, Detroit, Mich.
Kirby, Frank E., Detroit Dry Dock Co., Detroit, Mich.
Leland, Henry M., Leland & Faulconer Mfg. Co., Detroit, Mich.
Lewis, Jacob F., Public Lighting Commission, Detroit, Mich.
Livingstone, William A., 40 Eliot st., Detroit, Mich.
Mahon, William L'E., 320 Atwater st., Detroit, Mich.
Marshall, Alfred C., Public Lighting Commission, Detroit, Mich.
Masson, George, 39 Columbia st., E., Detroit, Mich.
Mattsson, A. George, Dry Dock Engine Works, Detroit, Mich.
Maxwell, David, 820 Chamber of Commerce, Detroit, Mich.
McCrickett, Thomas F., Russel Wheel and Foundry Co., Detroit, Mich.
McMath, Francis C., Detroit Bridge and Iron Works, Detroit, Mich.
Molitor, David A., 41 Telephone Bldg., Detroit, Mich.
Molitor, Edward, 43 Telephone Bldg., Detroit, Mich.
Morley, H. Throop, 57 Canfield ave., W., Detroit, Mich.
Newkirk, Walter M., 36 Moffat Blk., Detroit, Mich.
Parks, George E., Mich. Central R. R. Car Shop, West Detroit, Mich.
Penton, John A., 37 Buhl Blk., Detroit, Mich.
Pettee, William H., 554 Thompson st., Ann Arbor, Mich.

Pope, Willard, Detroit Bridge and Iron Works, Detroit, Mich.
Porter, George F., Detroit Bridge and Iron Works, Detroit, Mich.
Raymond, Alexander B., Health Office, Detroit, Mich.
Riggs, Henry E., 613 The Nasby, Toledo, Ohio.
Robinson, George A., Board of Public Works, City Hall, Detroit, Mich.
Rummler, Eugene A., Detroit Dry Dock Co., Detroit, Mich.
Russel, Walter E., Russel Wheel and Foundry Co., Detroit, Mich.
Russell, C. W., Russel Wheel and Foundry Co., Detroit, Mich.
Sack, Richard E., Edison Illuminating Co., Detroit, Mich.
Sanborn, George W., T., H. & B. Ry., Hamilton, Ont.
Sanderson, Edmund L., 43 Alexandrine ave., W., Detroit, Mich.
Smith, Jesse M., 56 W. 39th st., New York, N. Y.
Steele, Walter D., 40 Atwater st., E., Detroit, Mich.
Stephens, Charles M., Mt. Clemens, Mich.
Strong, William E. S., Michigan-Peninsula Car Co., Detroit, Mich.
Torrey, Augustus, Mich. Central R. R., Detroit, Mich.
Tuthill, G. C., Mich. Central R. R., Detroit, Mich.
Weil, Chas. L., Agricultural College P. O., Mich.
Whitaker, Henry E., cor. Fourth ave. and Abbott st., Detroit, Mich.
Wight, Sidney B., Mich. Central R. R., Detroit, Mich.
Wilkes, Gilbert, 1112 Union Trust Bldg., Detroit, Mich.
Williams, Gardner S., 4 Valentine Place, Ithaca, N. Y.
Wisner, George Y., 34 Congress st., W., Detroit, Mich.
Woodard, Silas H., 34 Congress st., W., Detroit, Mich.
Woodruff, Edward L., 18 Bagley ave., Detroit, Mich.
Ziwet, Alexander, Ann Arbor, Mich.

Engineers' Society of Western New York.

Bardol, F. V. E., 13 City Hall, Buffalo, N. Y.
Bassett, Geo. B., 363 Washington st., Buffalo, N. Y.
Brackenridge, W. A., Cataract Construction Co., Niagara Falls, N. Y.
Fields, S. J., 632 Ellicott st., Buffalo, N. Y.
Gaskin, E. F., Union Dry Dock Co., Buffalo, N. Y.
Gorham, Marvine, 250 Elmwood ave., Buffalo, N. Y.
Green, H. B., 434 Guaranty Bldg., Buffalo, N. Y.
Guthrie, E. B., 158 North Pearl st., Buffalo, N. Y.
Hammond, Richard, Lake Erie Engineering Works, Buffalo, N. Y.
Houck, Wm. G., 97 High st., Buffalo N. Y.
Hubbell, Geo. S., 885 Ellicott Sq. Building, Buffalo, N. Y.
Humbert, W. S., 434 Guaranty Bldg., Buffalo, N. Y.
Johnson, Wallace C., Niagara Falls, N. Y.
Knighton, John A., 315 Grant st., Buffalo, N. Y.
Lufkin, E. C., 102 Anderson Place, Buffalo, N. Y.
March, H. J., 13 City Hall, Buffalo, N. Y.
Meyer, Carl, P. O. Drawer 170, Buffalo, N. Y.
McCulloh, Walter, Crick Block, Niagara Falls, N. Y.
McLeod, Wm. C., North Tonawanda, N. Y.
Morse, Chas. M., Erie Co. Bank Bldg., Buffalo, N. Y.
Norton, Geo. H., 13 City Hall, Buffalo, N. Y.
Powell, S. W., 679 Auburn ave., Buffalo, N. Y.
Patch, Maurice B., 1 Austin st., Buffalo, N. Y.
Rafter, Geo. W., 403 Bronson ave., Rochester, N. Y.
Ricker, Geo. A., 702 Ellicott Square Bldg., Buffalo, N. Y.
Robbins, Wm. D., Cataract Construction Co., Niagara Falls, N. Y.
Smith, T. Guilford, 9 German Insurance Bldg., Buffalo, N. Y.
Sornborger, E. C., 208 Lancaster ave., Buffalo, N. Y.

Tutton, C. H., foot Main st., Buffalo, N. Y.
Watkins, W. B., N. Y. Car Wheel Wks., Buffalo, N. Y.
Whitford, O. F., 79 Woodlawn ave., Buffalo, N. Y.
Teiper, Casper, Buffalo Structural Steel Wks., Buffalo, N. Y.
Hoek, J. Vander, Lehigh Valley Depot, Buffalo, N. Y.

Louisiana Engineering Society.

Armstrong, J. W., 622 Camp st., New Orleans, La.
Andry, Paul, Masonic Temple, New Orleans, La.
Bell, Alonzo C., City Hall, New Orleans, La.
Blakemore, A. B., N. O. Traction Co., New Orleans, La.
Bemiss, E. L., Edison Electric Co., New Orleans, La.
Brown, Jno. J., 715 Perdido st., New Orleans, La.
Brownlee, Jas. L., Custom House, New Orleans, La.
Coleman, J. F., City Hall, New Orleans, La.
Chamberlin, C. H., 106 Thalia st., New Orleans, La.
Charlton, H. W., City Engineer's Office, New Orleans, La.
Charlton, C. H., Jr., 204 Carondelet st., New Orleans, La.
DeBuys, R. E., 464 La Salle ave., Chicago, Ill.
D'Heur, Allard, Shelbyville, Ind.
Duval, Andre C., State Board Engineers, New Orleans, La.
Fox, John A., State Board Engineers, New Orleans, La.
Grandjean, Geo. H., 19 City Hall, New Orleans, La.
Harrod, B. M., City Hall, New Orleans, La.
Hoffman, W. H., State Board Engineers, New Orleans, La.
Haugh, Jas. C., Press and Levee sts., New Orleans, La.
Hardee, W. J., 3232 Prytania st., New Orleans, La.
Harrison, Geo. B., T. and P. R. R., Boyce, La.
Haygood, Geo. L., 921 St. Louis st., New Orleans, La.
Ivy, Ernest D., 220 Carondelet st., New Orleans, La.
Kirkland, W. C., City Hall, New Orleans, La.
Kerr, Frank M., State Board Engineers, New Orleans, La.
Kaiser, Albert R., City Engineer's Office, New Orleans, La.
Kay, William G., 3920 Tchoupitoulas st., New Orleans, La.
Llewellyn, F. T., 1012 Hennen Bldg., New Orleans, La.
Lombard, Gervais, Orleans Levee Board, New Orleans, La.
Lewis, Sidney F., State Board Engineers, New Orleans, La.
Lawes, G. W., Port Eads, La.
Lambert, E. L., City Hall, New Orleans, La.
Lion, L. E., 1010 Burgundy st., New Orleans, La.
Malochee, H. J., 121 Carondelet st., New Orleans, La.
McCutchon, A. D., N. O. and N. E. R. R., Vossburg, Miss.
McKinney, E. B., 1550 Constance st., New Orleans, La.
Mims, Lewis, 22 City Hall, New Orleans, La.
Perrilliat, Arsene, State Board Engineers, New Orleans, La.
Raymond, Thos. L., City Hall, New Orleans, La.
Richardson, Henry B., State Board Engineers, New Orleans, La.
Reynes, Chas. J., City Engineer's Office, New Orleans, La.
Robertson, M. P., State Board Engineers, Baton Rouge, La.
Smith, Wright, City Hall, New Orleans, La.
Stewart, Hunter, City Hall, New Orleans, La.
Swart, R., Baton Rouge, La.
Starling, William, 3232 Prytania st., New Orleans, La.
Theard, Alf. F., City Hall, New Orleans, La.
Thompson, H. Bolivar, State Board Engineers, New Orleans, La.
Tutwiler, Thos. H., N. O. Traction Co., New Orleans, La.
Wright, W. B., City Hall, New Orleans, La.
White, W. S., State Board Engineers, New Orleans, La.
White, E. P., 601 Hennen Bldg., New Orleans, La.
Waddill, Frank H., Masonic Temple, New Orleans, La.
Woolley, A. F., Jr., 3232 Prytania st., New Orleans, La.
Zander, Henry L., City Hall, New Orleans, La.

Engineers' Club of Cincinnati.

Anderson, Col. L., Kuttawa, Lyon county, Ky.
Archer, Wm., B. & O. S. W. Ry., Chillicothe, O.
Baird, Sam'l P., Portsmouth, O.
Baldwin, Bert L., 72 Perin Bldg., Cincinnati, O.
Baldwin, Hadley, C., C., C. and St. L. Ry., Indianapolis, Ind.
Baldwin, Prof. Ward, University of Cincinnati, Cincinnati, O.
Birch, Thos. H., 239 Mill st., Cincinnati, O.
Birch, Wm. W., 239 Mill st., Cincinnati, O.
Bogen, Prof. L. E., 547 Hale ave., Avondale, Cincinnati, O.
Bouscaren, G., City Hall, Cincinnati, O.
Breckinridge, Cabell, Danville, Ky.
Bryan, R. A., Portsmouth, O.
Burke, M. D., 404 Pike Bldg., Cincinnati, O.
Burke, S. E., P., C., C. & St. L. Ry., Richmond, Ind.
Caldwell, J. N., U. S. Engineer's Office, Cincinnati, O.
Carlisle, John, Carlisle Bldg., Cincinnati, O.
Carothers, D. D., B. & O. S. W. Ry., Cincinnati, O.
Carpenter, E. J., U. S. Engineer's Office, Cincinnati, O.
Chase, Frank L., 1035 Storey ave., Louisville, Ky.
Clark, John A., C., P. & V. Ry., Cincinnati, O.
Cowper, John W., C., C., C. & St. L. Ry., Mt. Carmel, Ill.
Creaghead, Thos. J., 802 Plum st., Cincinnati, O.
Devereux, H., B. & O. S. W. Ry., Cincinnati, O.
Diemer, Hugo, Equitable Bldg., Atlanta, Ga.
Doane, W. H., St. Paul Bldg., Cincinnati, O.
Dreses, Henry, Queen City ave. and Buck st., Cincinnati, O.
Elzner, A. O., 18 E. Fourth st., Cincinnati, O.
Engle, R. L., 1530 Westminster ave., Cincinnati, O.
Ewing, Chas. A., Box 53, San Jose, Costa Rica, S. Am.
Fenton, B. W., F., Ft. W. & W. Ry., Findlay, O.
Flinn, E. T., So. Pac. Co., Tucson, Ariz.
Fox, Frank A., 419 Main st., Cincinnati, O.
Fritch, L. C., B. & O. S. W. Ry., Washington, Ind.
Garrard, Col. Jeptha, 407 Johnston Bldg., Cincinnati, O.
Glazier, W. L., Newport, Ky.
Goldfogle, David, Dennison Hotel, Cincinnati, O.
Gordon, C. M., Georgetown, O.
Gray, Geo. A., Gest and Depot sts., Cincinnati, O.
Hamkens, H., John and Water sts., Cincinnati, O.
Harper, Jas. M., City Engineer's Office, Cincinnati, O.
Hauck, A. L., 3712 Warsaw ave., Cincinnati, O.
Hayward, A. W., St. Paul Bldg., Cincinnati, O.
Hazard, Schuyler, C., C., C. & St. L. Ry., Cincinnati, O.
Hazen, A. T., 809 Broadway, Cincinnati, O.
Hazen, L. P., 809 Broadway, Cincinnati, O.
Hilgard, K. E., St. Paul, Minn.
Hoag, I. V., 170 South ave., Allegheny City, Pa.
Hobby, A. S., 33 Wiggins Block, Cincinnati, O.
Hoeffer, H. L., 809 Broadway, Cincinnati, O.
Hosbrook, J. A., 430 Pike Bldg., Cincinnati, O.
Howe, E. G., C., H. & D. Ry., Cincinnati, O.
Hosea, L. M., 404 Johnston Bldg., Cincinnati, O.
Innes, H. C., Hartwell, O.
Jewett, Wm. C., 541 Ridgeway ave., Cincinnati, O.
Kittredge, Geo. W., C., C., C. & St. L. Ry., Cincinnati, O.
Koch, H. A., A. & V. Ry., Vicksburg, Miss.
Laidlaw, Walter, Pearl and Plum sts., Cincinnati, O.
Lane, H. M., John and Water sts., Cincinnati, O.
Lietze, Ernst, 13 Longworth st., Cincinnati, O.
Lilly, Jas. A., C., L. & N. R. R., Cincinnati, O.
Lindsay, Chas. E., R. M. Southern Ry., Manassas, Va.
McAvoy, Irving, Gila Bend, Ariz.
Meeds, C. H., Winton Place, O.
Miller, C. N., City Hall, Cincinnati, O.

Morris, Frank E., 2846 Harrison ave., Cincinnati, O.
Nelson, John C., C., C., C. & St. L. Ry., Springfield, O.
Nicholson, G. B., Odd Fellows' Temple, Cincinnati, O.
Osborn, S. J., Pearl and Eggleston ave., Cincinnati, O.
Petry, Alfred, California, O.
Pfister, Herman, 428 Plum st., Cincinnati, O.
Punshon, Thos. B., Cincinnati, O.
Rabbe, J. A., 404 Pike Bldg., Cincinnati, O.
Randolph, Epes, So. Pac. Co., Tucson, Ariz.
Read, R. L., 32 E. Third st., Cincinnati, O.
Ruggles, W. B., 32 E. Third st., Cincinnati, O.
Scarborough, F. W., C. & O. Ry., Hinton, W. Va.
Schreiber, Chas., 623 Eggleston ave., Cincinnati, O.
Siefert, F. J., City Engineer's Office, Cincinnati, O.
Stanley, H. J., Eighth and Plum sts., Cincinnati, O.
Stewart, Jas. A., 517 Johnston Bldg., Cincinnati, O.
Strack, T. P., Ninth and Plum sts., Cincinnati, O.
Thompson, Chas. P., John and Water sts., Cincinnati, O.
Totten, A. L., Glen Mary, Tenn.
Totten, W. H. D., Neave Bldg., Cincinnati, O.
Venable, M. W., 56 Capitol st., Charleston, W. Va.
Venable, W. M.
Walsh, M., C., N. O. & T. P. Ry., Somerset, Ky.
Walter, H. B., 809 Broadway, Cincinnati, O.
Warder, R. H., City Hall, Cincinnati, O.
Warrington, H. E., Odd Fellows' Temple, Cincinnati, O.
Weir, Fred C., Front and Smith sts., Cincinnati, O.
Whinery, S., 81 Fulton st., New York, N. Y.
White, I. F., C., H. & D. Ry., Hamilton, O.
Wilson, C. A., C., H. & D. Ry., Cincinnati, O.
Wilson, J. F., City Hall, Cincinnati, O.
Wilson, W. A., Ninth and Plum sts., Cincinnati, O.
Wrampelmeier, F., C., N. O. & T. P. Ry., Somerset, Ky.
Wulff, A. G., 459 Riddle road, Cincinnati, O.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. JULY, 1899. NO. 1.

COVERED RESERVOIRS AND THEIR DESIGN.

BY FREEMAN C. COFFIN, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 17, 1899.]

THE use of covered masonry reservoirs for the storage and distribution of underground water is becoming so general, wherever the elevation and local conditions admit, that a brief consideration of the reservoirs of this class which have been built, a study of the elements which enter into the design and an investigation of the cost of various sizes and depths of such reservoirs can hardly fail to be of interest.

Stand pipes, tanks or metal structures of any description, although used for the same purpose as earth or masonry reservoirs, are of a nature so essentially different that further reference to them is unnecessary in this paper. The covered reservoir is in the line of natural evolution from the open distributing reservoir, to meet the requirement of exclusion of light from underground or filtered water, although the necessity of providing a roof or covering of some kind leads to a different disposition of materials.

SOME EXISTING RESERVOIRS.

In referring to reservoirs that have been built no attempt will be made to treat the subject exhaustively, nor to go to ancient history for examples. A few prominent types will be very briefly described.

SOME ENGLISH RESERVOIRS.

In the Proceedings of the Institution of Civil Engineers, Vol. LXXIII, in the year 1883, Mr. William Morris describes a number

of covered reservoirs built in England. In the discussion that follows several others are described. Among them is nearly every type of roof covering that has since been built in this country. The arches of these roofs were all of the segmental barrel form. Their spans were from 7 to 17 feet in the clear, their rise from one-eighth to one-third of the span. In the earlier examples the arches were sprung from wrought iron girders, these in turn being supported by cast iron pillars. In later construction brick piers were substituted for the pillars, and later still brick lintel arches springing from brick piers supported the main arches. No groined arches were included among these examples of reservoir vaulting. Although concrete is employed extensively in the construction of the reservoirs, it is used in the covering arches in only two instances. Except for the spandrel filling, they are of brick in the others. In the cases where concrete was used the clear spans were 12 feet, and the rise 2½ feet in both. In one it was 9 inches thick at the crown and 18 at the skewback, in the other 10 and 20 inches respectively. But two of these reservoirs were circular in plan, the others being square or rectangular. In one of the circular ones the covering arches were concentric, and were supported on rings made of 12-inch iron I beams resting upon brick piers. The other round reservoir had a vaulting of unique design. It was 64 feet in diameter, constructed with nine radial arches springing from 12-inch I beams, which rest upon a large cast iron column in the center and upon the outer walls. The iron girders have a slope of 4 feet from the center to the wall. The arches have a span of 22 feet and a rise of 4 feet at the wall; the crown is level, while the span and rise diminish to nothing at the center. The thickness of nearly all of the arches was about 8 inches, or two rings of brick laid on edge.

The side walls were generally rather heavy. In one reservoir they were very light. These were of brick 14 inches thick, built in the form of vertical arches, with 10-foot span and a very slight rise. There was a brick buttress or pier at the springing of each arch. This form being designed to resist the pressure from the outside, it is evident that the inside pressure of the water was supported by the earth backing. These reservoirs are described in detail in the paper, and are illustrated by plates. English practice of that date is quite fully described in the paper and the discussion that follows.

In a paper published in the journal of the N. E. Water Works Association for September, 1888, Mr. Charles H. Swan describes some very interesting covered reservoirs in France. The following extract from his paper refers to one of the most striking features of the reservoir of Menilmontant: "The reservoir is covered by

groined arches composed of two courses of bricks laid flat in cement. They rest upon pillars 60 centimeters (2 feet) square and 6 meters (20 feet) between centers. . . . The brick arches are about 8 centimeters ($3\frac{1}{4}$ inches) in thickness, including the plastering. They were covered by a layer of earth and turf 40 centimeters (16 inches) thick."

AMERICAN RESERVOIRS.

There are at present a number of covered reservoirs in this country. The following is a brief description of several of these:

Newton Reservoir.

One of the earlier of these was built for the water works of the city of Newton, Mass., in 1890 and 1891. It was designed and built by Mr. Albert F. Noyes, city engineer. It is about 125 feet wide by 175 feet long and 15 feet deep. The walls are of rubble masonry, laid in Rosendale cement mortar, about $7\frac{1}{2}$ feet thick at the bottom and $2\frac{1}{2}$ feet on top on two sides and 5 feet on the other two. The covering is of brick arches 4 inches thick, with a clear span of 10 feet and about 10 inches rise. The arches are supported by rows of lintel arches of brick, which rest upon brick piers 20 inches square. The top of the arches is filled up level with concrete to a point 4 inches above the crown. Over this is a filling of earth about $2\frac{1}{2}$ feet thick.

Brookline Reservoir.

A covered reservoir was constructed for the water works of Brookline, Mass., in 1892. It is about 92 feet square and 19 feet deep; its construction is similar to that at Newton, except that the walls and piers are heavier. A description of it is given in a paper read by the engineer, Mr. F. F. Forbes, and published in the journal of the N. E. Water Works Association for March, 1894. These reservoirs are excellent examples of substantial construction.

Franklin Reservoir.

In the year 1891 Mr. F. L. Fuller, civil engineer, built a reservoir of admirable design and economical construction at Franklin, N. H. It is circular in plan, 70 feet in diameter and about 17 feet deep. The walls are of rubble masonry laid in Rosendale cement mortar, are 5 feet thick at the bottom and $2\frac{1}{2}$ feet at the top. The covering consists of two concentric brick arches and a central dome. The latter is 23 feet in diameter, with a rise of 3.25 feet. The arches have a clear span of 11 feet, and rise 1.50 feet; the thickness of the arches and dome is 8 inches. They are supported by two

rings of lintel arches and the side walls; the piers of the lintels are of brick, 1 foot square and 7 feet apart in the rings. The piers are much smaller for their load and length than it is customary to make them, and are certainly an interesting example of the extent to which ordinary practice can be departed from with success. Mr. Fuller has since built similar ones at Methuen and Winchendon, Mass. A description of this reservoir is given in the journal of the N. E. Water Works Association, 1892, page 82.

Waltham Supply Well.

In the journal of the N. E. Water Works Association for March, 1894, there is an interesting description of the covering of a supply well at Waltham, Mass., by Mr. Frank P. Johnson, civil engineer. There are arches similar to those at Newton and Brookline; these have a clear span of 11.5 feet, rise of 1.92 feet and are built of one 4-inch ring of brickwork with no concrete filling over them. There is also a circular dome 40 feet in diameter, 7 feet rise, built of what were called Guastavino tiles 1 inch thick; there were three thicknesses of these tiles in the domed covering. They foot at the skewback on a metal ring, which resists the outward thrust.

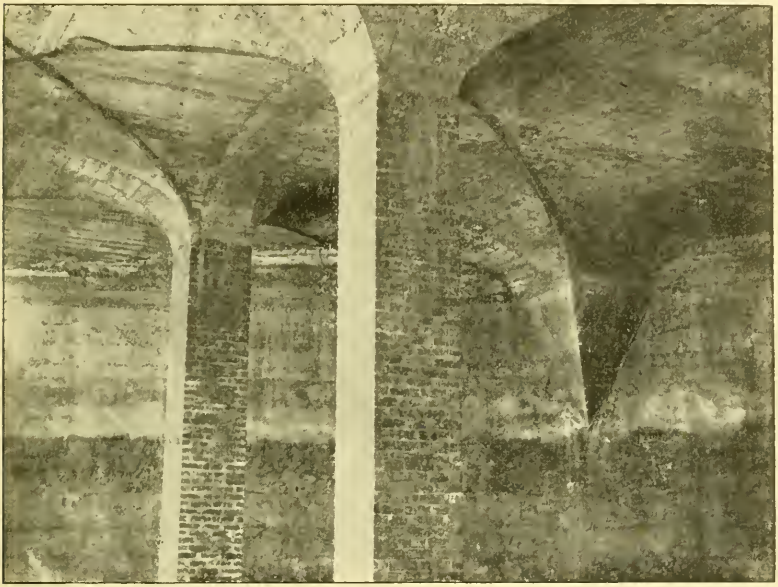
Wellesley Reservoir.

During the summer of 1898 the writer constructed some works for an additional supply of water for the town of Wellesley, Mass. The supply is an underground one, which was recommended by Mr. Desmond FitzGerald after a thorough investigation of all available sources. A covered reservoir of a capacity of 600,000 gallons was included in his recommendations. Mr. FitzGerald acted as consulting engineer in the design and construction of the works.

In designing the reservoir many types were considered, and it was finally decided to build it circular in plan, with a roof or covering of elliptic groined arches. It was first thought that such arches were not adapted to a circular reservoir, but further study showed that no real difficulties were involved. Designs for several depths were computed, and it was found that a depth of about 15 feet and diameter of about 80 feet was more economical for the required capacity than a greater depth. The dimensions of the arches and piers finally adopted fixed the inside diameter at 82 feet, and the depth from the floor to the springing line of the arches was made 15 feet. For a capacity of 600,000 gallons the water line is about 0.7 feet above the spring line, and the overflow was fixed at that point. Material for concrete was more available

than for rubble masonry, and the walls were designed of that; it was also decided to make the roof of concrete, as its cost is much less per yard than brickwork; and with the latter the thickness of the arches could not be made much less, besides this form of arch requires a great deal of cutting of the brick. The centering for concrete costs more, as it must be made tight and smooth; while that for brick can be made with a covering of narrow strips. Brick was chosen for the piers. The dimensions of the parts of the reservoir as designed were as follows:

Walls 15 feet high from floor to spring line, 2 feet thick for 5 feet below the spring line, 2.67 feet in the next lower 5 feet, 3.33



INTERIOR OF RESERVOIR SHOWING GROINED ARCHES.

feet in the lowest section. Piers 15 feet total height, 2 feet square, with a base 2.67 feet square at bottom. Foundations of piers 3.5 feet square, 1 foot deep. Roof arches 12 feet clear span, 2.5 feet rise, 0.5 feet thick at the crown, filled in level over the piers. The material of the excavation was a tight, clayey hardpan with very little water in it; the floor was therefore made only 4 inches thick. A steel ring of channel iron, weighing 32 pounds per foot, was set in the side walls just above the spring line. The earth filling over the concrete roof was designed as follows: Six inches of clean gravel next the concrete for drainage, and to prevent freezing to the concrete; this gravel went over the sides to the spring line, and was

drained by several lines of 4-inch vitrified pipe, which discharge at the toe of the embankment. Over the gravel 1 foot of earth from the excavation and then 6 inches of loam, making a total of 2 feet. The embankments were carried out at the level of the top to a point 7 feet outside of the inside line of the wall, and thence to the natural surface with a slope of 2 to 1.

The construction was executed as designed, with two exceptions. A great many bowlders were found in the excavation; the specifications provided that "the lower part of the wall might be made of these stones if the engineer should so direct, in which case it is probable that the thickness of the wall will be increased." This was done, and the wall made 4 feet at the bottom, or 8 inches thicker than designed, as shown in Fig. 1. It was thought that it would not be possible to make as strong work with these bowlders as with concrete. The smooth, rounded stones were split, the rubble laid against forms and so carefully bedded in the mortar that the writer is of the opinion that it would have been perfectly safe to have used the thickness designed. The other change was in the thickness of the earth covering. There being a surplus of loam, it was put on 1 foot thick, instead of 6 inches. This made the total thickness of the earth $2\frac{1}{2}$ feet at the walls and 3 feet at the center.

Portland cement was used throughout. That in the walls was the Brooks-Shoobridge brand; the vaulting was of Alsen, with the exception of about one hundred barrels of Atlas that was used because the Alsen could not be had in time. The concrete made of the Atlas seemed quite as good as the other. The number of parts of sand used to one part of cement were as follows: In rubble masonry $2\frac{1}{2}$, in the concrete in the walls 3, in the vaulting $2\frac{1}{2}$. The proportion of screened gravel used in the concrete was such that the voids were slightly overfilled. It required approximately 1.1 barrels of cement per cubic yard for the rubble masonry, 1.2 barrels for the concrete, with 3 parts of sand, and 1.3 for that with $2\frac{1}{2}$ parts. These figures are based upon the total amount of each kind of work and the number of barrels used in that work.

A ring made of channel iron, weighing 32 pounds per foot, was set in the side walls, with its bottom at the spring line of the roof arches. The bottom of the reservoir is covered with a floor of concrete 4 inches thick. This floor and the side walls are finished with two coats of plaster; one about $\frac{1}{2}$ inch thick, of mortar mixed in the proportion of 2 of sand and 1 of cement; this coat was leveled up, but not smoothed. The last coat was of neat cement, about $\frac{1}{8}$ of an inch thick, thoroughly rubbed in and smoothed with trowels. There were a few places where the walls were moist from the pres-

sure of the water on the outside, and some trouble was anticipated in making a good work with the plastering; but very little was realized, and it was in the best of condition when the reservoir was filled. The roof was not absolutely tight, and a very heavy rain coming on just as the plastering of a part of the floor was finished, there was some dropping of water in several places, which cut through the $\frac{1}{8}$-inch coat before it was hard and threw off a number of flakes. This made it necessary to plaster over a small portion of the floor. Twelve hours more of setting before the rain would have prevented this; the expense was, however, but a few dollars.

The centering for a roof of this type is an important and expensive factor in the work. Plans were made for centers that would each cover the space between four piers. The contractor believed that it would be better to reduce the size of the single centers, and, as he was not required to adopt the plans of the engineer if his own were satisfactory, he was allowed to use the smaller ones. The writer believes that the extra fitting caused by this change made the total cost of the centering much more than it would have been if the original plans had been followed. Whether this is so or not, the cost of the centers (if used but once), of the supporting timbers and the labor of erection and removal was about $22\frac{1}{2}$ cents per square foot for the inside area of the reservoir. The contractor's plan was to supply centers for one-quarter section of the reservoir only, and put the roof on in such sections. This was assented to by the engineer, with the provision that the heads of the piers should be thoroughly braced in each direction to the outside walls, and that if it was found necessary to have more centers in order to prevent delay they should be provided. Although a large saving in cost of centers would be made in this way, it is a mistaken policy, as it afterwards proved in this case. While it is quite possible to do the work in this way if the piers are braced and kept braced, there is a liability that the braces may be removed without the knowledge of those who realize the danger of their removal, as happened here. When one-half of the reservoir had been arched over in quarter-sections at a time, and the centers were being set for the third section, the center row of piers, or those supporting the outer edge of the finished half of the roof, were overturned, and the arches between them and the next row fell, killing one man, breaking the leg of another and slightly injuring two more. It was just after seven o'clock, and neither the contractor nor the inspector was present. It was found upon investigation that three and, as two of the carpenters testified, four out of five braces that resisted the thrust on this row of piers had

COMMONWEALTH OF MASSACHUSETTS.

State Board of Health. Wellesley.

WATER ANALYSIS.

PARTS IN 100,000.

	No.	Date of: Collection.	Date of: Examination.	Appearance: Turbidity.	Appearance: Sediment.	Appearance: Color.	Odor: Cold.	Odor: Hot.	Residue on Evaporation: Total.	Residue on Evaporation: Loss on Ignition.	Residue on Evaporation: Fixed.	Ammonia: Free.	Ammonia: Albuminoid: Total.	Ammonia: Albuminoid: In Solution.	Ammonia: Albuminoid: In Suspension.	Chlorine.	Nitrogen as: Nitrates.	Nitrogen as: Nitrites.	Oxygen Consumed.	Hardness.	Iron.	REMARKS.
Water Not in Use	21741	1898. Jan. 3	1898. Jan. 4	Slight	Slight	.03	Faintly Mouldy	Distinctly Mouldy	10.20	....	....	.0428	.0186	....	....	.71	.2650	.0002	.12	4.3	0020	New Covered Reservoir
Water Not in Use	21917	Jan. 19	Jan. 20	Slight	Slight	.05	None	None	12.10	....	....	0762	.0344	....	....	.73	.2400	.0001	.24	3 8	.0010	
Water Not in Use	22096	Feb. 7	Feb. 8	Slight	Slight	.05	None	None	10.30	....	....	.0040	.0076	....	....	.70	.1850	.0003	.06	3.9	.0020	
In Use	22786	April 11	April 11	None	None	.01	None	None	6.90	....	....	.0002	.0014	....	....	.57	.0830	.0000	.02	3.4	0060	
In Use	26037	1899 Jan. 25	1899 Jan. 26	None	None	.00	None	None	6.5[illegible]	....	....	.0014	0042	....	....	.56	.0840	0000	01	3.1	0010	

The color of water is expressed by numbers which increase with the amount of color. Boston water, as drawn from a tap at the State House, had an average color in 1898 of 0.41. Other water supplies in the State had an average color of from 0 to 1 39.

All waters containing suspended matter, excepting ground waters which contain a large quantity of iron, are filtered through filter paper before determining the color and residue on evaporation. Occasionally these determinations are also made on the unfiltered water, the results in such cases being indicated by an asterisk.

been removed. It transpired afterwards that the braces had been removed from the first section in the same way, and the tensile strength of the concrete was sufficient to keep the arches intact. There was a greater load on the half-section, as a portion of the covering had been put on.

With the exception of this unfortunate accident, the work on the reservoir was very successfully carried out. The contractor, Mr. Donato Cuozzo, took a great personal interest in having the character of the work of the very best, and used every effort to make it so. When finished the reservoir was filled and allowed to stand for some weeks without any draft upon it; there was practically no loss of water from it. The effect upon the water, as shown by a chemical analysis, of standing without change in this new reservoir was marked. The cause of this has never been explained. The results of the analyses on the preceding page (made by the State Board of Health) show in what way it was affected.

A plan and section of this reservoir is shown in Fig. 1.

The reservoir has now been in use about fifteen months with satisfactory results. The final quantities, their contract price and the total cost of the reservoir, aside from any expense caused by the accident, are given below:

3446.20	cubic yards earth excavation	@ $0.40	$1,378.48
24.50	" " rock "	@ 2.50	61.25
309.80	" " rubble masonry	@ 3.10	960.38
502.86	" " concrete	@ 3.50	1,760.01
61.22	" " brick	@ 10.50	642.00
143.30	" " gravel	@ 1.00	143.30
484.50	square " plastering wall	@ .20	96.90
570.30	" " " floor	@ .20	114.06
438.60	cubic " loam in place	@ .20	87.72
	Setting pipes, gates, etc		100.00
	Seeding and sodding		60.00
148.	vitrified pipe	@ .25	37.00
	Channel iron ring		350.00
	Bracing, sheeting and centers		500.00
	Payment to contractor		$6,291.91

In addition to the above there are the following items that were outside of the contract:

Portland cement	$3,156.18
Cast iron pipe, special castings, gates and gate boxes	464.32
Special ironwork	77.34
Hauling sod	21.38
Gravel in the pit	65.00
Carpenter work on brick house for telemeter	138.93
I beams for same	24.00
Telemeter transmitter and wiring	70.80
Blacksmith work	15.00
Sodding not done the first season about	90.00
Total of extra items	$4,122.95
Total cost	$10,414.86

THE DESIGN OF COVERED RESERVOIRS AND WATER FILTERS.

The controlling factors in the design of covered reservoirs for water or sewage and in that of the structure that contains the filtering materials or the filter bed in a water filter of the "sand filtration type," where the latter must be covered, are so similar that the design of both can very well be treated in the same paper. The following discussion of such design is intended to refer to both in so far as it relates to their common features. It will be readily perceived when the discussion refers to considerations peculiar to only one of the subjects, as, for instance, that in regard to the economic ratio of depth to area, which refers only to the reservoirs. For convenience, the word reservoir will be used in referring to the subject of the paper.

The required capacity of the proposed reservoir having been determined, which determination is independent of the design of the reservoir itself, its form is naturally the first question to be considered. If the choice is not restricted by topography or property lines, either the square or circular form would naturally be chosen. Which of these is the more economical may depend upon local conditions, the relation of depth to area, or to other factors in the case. The natural inference is that the circular form would require less materials in its construction. Where land is expensive the square one might be the cheaper. The cost of each type under various conditions will be given in this paper. As the form departs from the square or the circle the cost increases for the same capacity, since the length of the side walls is greater in proportion to the inclosed area; therefore economical design does not permit a departure from these two forms except where it is rendered necessary by the shape of the lot or the topography of the ground.

The relation of depth to area must next be determined; there seems to be nothing to indicate with any certainty what this ratio may be. The amount of excavation is about the same for any ratio; the cost of the roof, floor and piers will increase directly with increasing area; the cost of the side walls increases about as the square root of the area. On the other hand, an increase in depth involves an increase in the cost of the walls, which is greater than that of their depth, owing to the increasing thickness of the bottom. In an absolutely scientific design the material in the piers will increase faster than their depth, due to the necessity of making their horizontal dimensions greater as their length increases. If not altogether impossible, it would be very difficult to construct a formula that would combine all of these factors and give the economic ratio. An endeavor will be made in this paper to pro-

vide a means of ascertaining this ratio for certain types of reservoirs without having recourse to the tedious method of designing and estimating upon several reservoirs of different dimensions. In the discussion of the design of a reservoir the several parts will be treated separately.

ROOF, OR VAULTING.

The design of the vaulting is more independent than that of the other parts, and their design is largely influenced by it; therefore the first consideration will be given to it. This paper is intended to treat wholly of masonry or imperishable construction, and no attention will be given to roofs of other types, although such may be quite satisfactory under some conditions.

The choice of material for the arches is practically confined to two kinds. Brick is the material of which most of the covering arches have been made. The use of concrete is increasing rapidly at the present time, and, when properly made with Portland cement, it cannot be surpassed. Its cost per cubic yard is about one-half that of brick masonry, and it is not necessary to use a greater quantity than of the latter. However, either makes an excellent vaulting, and the choice may often depend upon the local availability of the material. Concrete was used in the arches of the Wellesley reservoir, and in one built by Mr. F. L. Fuller for the State Hospital for Epileptics at Palmer, Mass. The vaulting of filter beds built by Mr. Allen Hazen at Albany is also of the same material. A sewage reservoir that is being built at Clinton by the Metropolitan Water Board is to be covered with concrete. As concrete can be placed in any form with little trouble, almost any type of arch may be selected. Consideration must of course be given to the comparative difficulty of making the centers.

Groined elliptic arches offer many advantages: the quantity of the material required is small; there is a clear head room in each direction, which is not the case with barrel arches; and the arrangement is good for ventilation. With groined arches both lintel arches and iron girders are avoided. This type was adopted by Mr. Wm. Wheeler in the composite brick and concrete arches of the filter beds at Ashland, Wis., and Somersworth, N. H. It was also adopted for the concrete arches of the Wellesley and Clinton reservoirs, and by Mr. Hazen for the Albany filters. The dimensions of the arches in the first two instances were as follows: Clear span 13.75 feet, rise 3.50 feet, thickness at crown about 5 inches, or the thickness of two bricks laid flatwise. By a curious coincidence, which was the result of independent study, the Wellesley and Albany arches have exactly the same dimensions,—namely,

clear span 12 feet, rise 2.50 feet, thickness at the crown 0.50 feet. In the Clinton reservoir the span and rise is to be the same, and the thickness of the crown is to be 1 foot. The thickness of the earth covering is about twice as great as in the other cases. This study of design will be limited to elliptical groined arch vaulting, with especial reference to the use of Portland cement concrete.

The determination of the unit pressures is rather uncertain. When built of concrete, and to a certain extent when built of brick in cement, an arch of this form is monolithic, and a portion of the internal stress is resisted by the tensile strength of the material, instead of being wholly in compression, as in a barrel arch. The stresses, in a section of the arch normal to the axis and in line with the piers, are probably compressive in as far as they are caused by the load upon that section. Since there is no diagonal rib or arch

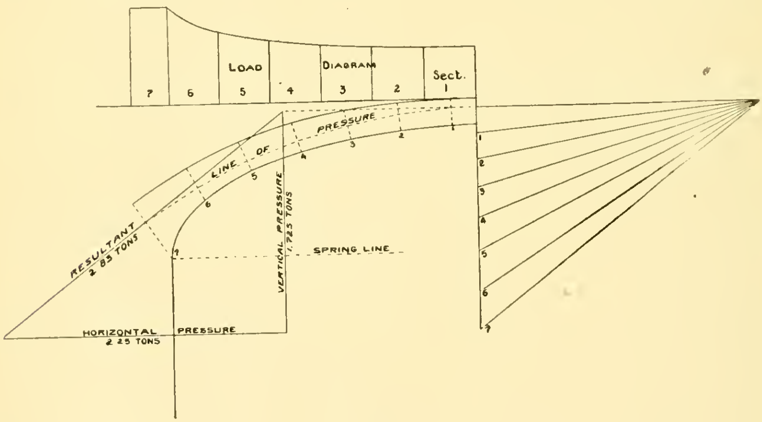


FIG. 2.

at the groin to carry the pressures caused by the load on the flanks of the arches to the piers, these pressures must be distributed by the tensile strength of the material between the normal arch and a certain portion of the groin in a way that would seem to defy mathematical treatment.

It is impossible, however, to secure a bond between new work and that already set, in which the adhesion of the new to the old is equal to the cohesion in the body of the material. In work of much extent such bonding cannot be avoided. Contraction cracks are also quite sure to occur in large areas of masonry. In view of these considerations, it is probably wise to neglect the tensile strength, or at least give it but little weight, and, if any consideration is to be given to computed pressures, to calculate them approximately, under the most unfavorable conditions.

The load on the arches is their own weight, that of the earth covering, the water that it holds in saturation, ice and snow and whatever load of people may come upon it. As a distributing reservoir is usually in a sightly place, the last item must be given due weight, unless thorough provision is made to exclude them.

Fig. 2 shows a section, normal to its axis, of an arch with a clear span of 12 feet, rise of 2.50 feet and thickness at crown of 0.50 feet; also a graphical representation of the pressures in a unit section of 1 foot. These dimensions are taken as being identical with two recent examples actually built, with the exception of the thickness, of one that is being built and because there seem to be reasons for using about these dimensions. (The latter is opinion only, and cannot be demonstrated except by a great deal of work in designing and computing those of different dimensions and estimating their effect upon other parts of the reservoir.)

Table No. 1 gives the loads, and Table No. 2 gives the unit pressures at the different points of the arch shown in Fig. 2.

Table No. 1.

Loads on Normal Arch.

No. of Sect.	Area of Concrete, Sq. Ft.	Wt. of Concrete, Lbs.	Wt. of Earth, Lbs.	Wt. of Snow and Ice, Lbs.	Wt. of People, Lbs.	Total Weight, Lbs.	Total Weight, Tons.
1.......	0.52	78	250	.25	50	403	.202
2.......	0.60	90	250	25	50	415	.207
3.......	0.72	108	250	25	50	433	.216
4.......	0.97	145	250	25	50	470	.235
5.......	1.34	201	250	25	50	526	.263
6.......	1.98	297	250	25	50	622	.311
7.......	2.25	337	187	19	38	581	.290

Total load on one foot section of half-arch..................1.724

Table No. 2.

Average Unit Pressures on Normal Arch.

No. of Joint.	Total Press. on Joint, Tons.	Area of Joint, Sq. Ft.	Average Unit Pressure per Sq. In., Lbs.	Average Unit Pressure per Sq. Ft., Tons.
1................	2.26	0.50	62.80	4.52
2................	2.29	0.53	60.	4.33
3................	2.33	0.56	57.60	4.15
4................	2.41	0.59	57.	4.10
5................	2.52	0.62	56.	4.03
6................	2.67	0.70	53.	3.81
7................	2.90	1.33	30.20	2.18
At crown........	2.25	0.50	62.50	4.50

As the arch proper and the spandrel filling are one mass, in computing the pressures the extrados of the arch must be assumed. In Fig. 2 a thickness was found by trial in which the unit pressures would nowhere exceed that at the crown, and in which the line of pressure would lie wholly within the middle third. The average unit

pressure at the crown is 4.50 tons, and as the line of pressure at this point is one-third of the thickness from the outside; if the material is considered as inelastic the maximum unit pressure will be twice the average, or 9 tons. This is probably the greatest pressure in the arch. The line of pressure is also at one-third of the thickness from the soffit near the point called joint 5. At all other points the line of pressure is well within the middle third, and the maximum pressures are less. There seems to be no way in which the unit pressures in the groin can be determined with much precision, as there is no separate rib or arch in which to compute them. If a width is assumed for a rib the pressures in it are modified by the tensile strength of the material of which it is a part; this must prevent the result from being even approximately correct. The unit pressures at and near the groin are probably slightly in excess of those in the normal arch. This opinion is based upon some rough approximations. It is, however, hardly worth while to make elaborate calculations to find these

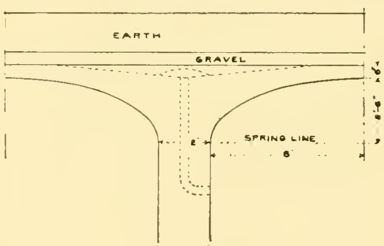


FIG. 5.

pressures; there are several examples of this type of arch with a thickness of 6 inches at the crown in actual existence. If it is desired to make a saving in material from that required by this thickness, it will be better to depress the filling over the piers and leave the crown thickness 6 inches. The arches of the Albany filters were made with such a depression; this is shown by the dotted lines in Fig. 3. This depression was filled with clean gravel and drained into the filter by pipes set in the piers. These pipes are also shown by dotted lines in Fig. 3.

Where it is permissible to drain the water that seeps through the earth covering, to the inside, this is in some respects better than a flat surface; some concrete is saved without weakening the arch, and the drainage of the top of the vaulting is freer.

The amount of material in cubic yards in vaulting when constructed as shown in Fig. 3 is given in Diagram No. 1. This is designed to give the quantity within the inside lines of the side walls for different dimensions of square and circular reservoirs

($2\frac{1}{2}$ per cent. excess is allowed to cover variations). The cost per cubic yard of concrete in the vaulting is probably no greater than in other parts of the reservoir if the cost of the centering is not included, but treated as a separate item. The cost of the centers, their supports, placing and removing them, is from 15 to 20 cents per square foot for the interior surface of the reservoir if it is all centered at once. If it can be centered and covered in sections the cost of centering will be greatly reduced.

EXCAVATION AND EMBANKMENT.

When it is possible to do so, as it usually is in a distributing reservoir, economy demands that the material from the excavation shall be approximately sufficient to make the embankment. For ordinary conditions Fig. 4 shows a good design for the embankment of either a square or circular reservoir, or for a filter that is partially in embankment.

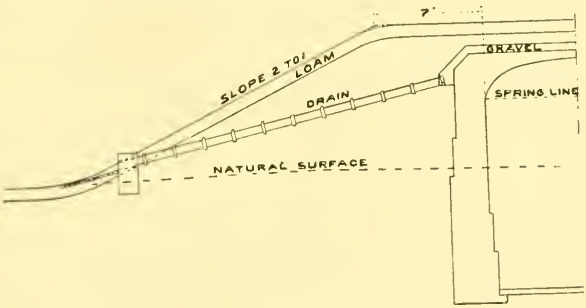


FIG. 4.

Diagram No. 2 gives the quantities of excavation and embankment in square and circular reservoirs of different depths and dimensions.

Trial computations to determine the elevation at which the excavation will balance the embankment are usually tedious. A few minutes' work with Diagram No. 2 will determine this so nearly that one check computation will enable it to be fixed as nearly as it is possible to do. If the site is level the results from the diagram are correct; if it is not level, take the average elevation of the ground to be covered by the reservoir and its banks, and the result will be approximately correct. One exact computation will then show whether it should be raised or lowered a trifle. Ten per cent. is allowed in the diagram for shrinkage. The method of finding the elevation, or, in other words, the depth below the average of the surface, that the bottom of the reservoir should be placed is as follows: After the required horizontal dimension and

total depth are determined, find on the lines of the diagram, which represent the diameter of a round reservoir, or the length of side of a square one, a depth of excavation and a height of embankment that both fall upon the same horizontal line representing quantity in cubic yards, and together equal the total depth of the reservoir from the floor to the water line. Note.—When reading quantities in excavation the scale for diameter or length of side must be read at the bottom of the diagram, this scale reading from right to left; while the dimensions must be read at the top when quantities in embankment are required, this scale reading from left to right.

Generally more than one trial will be necessary to find a depth of excavation and height of embankment the sum of which will just equal the total depth of the reservoir, somewhat as follows: If a proposed circular reservoir is to be 100 feet in diameter and 15 feet deep, assume for first trial that the depth of excavation will be 8 feet. Then on the diagram at the left, for round reservoirs, find the intersection of line for 8 feet depth with that of 100 feet diameter; read on the bottom scale. At this intersection the horizontal line has a value of 2960 cubic yards. Following this line across to the line for 100 feet diameter on scale for embankment, read at the top, we find that value of the curve for embankment intersecting at this point is 6 feet below the water line. Therefore, the total depth of a reservoir that an excavation of 8 feet would provide embankment for is 8 plus 6, or 14 feet; but the required depth is 15 feet, and another trial must be made. Less than 1 foot must be added to the 8 feet of the first trial. Trying 8.6 feet as nearly as it can be read, following the same process as before, we find 3160 yards of excavation and a trifle less than 6.5 feet for the embankment below the water line, making a total of practically 15 feet. Owing to the uncertainty in the actual shrinkage of any soil, a determination within one- or two-tenths of a foot is near enough for practical purposes. The actual amount of the embankment measured in place will, of course, be only 90 per cent. of that read from the diagram, as that includes the 10 per cent. for shrinkage.

N. B.—Depth of reservoir or "depth" when used in the diagram always means the depth of water from floor to high water line.

If the reservoir is located in a hollow, the excavation will be some less than the diagram gives, using the average elevation of the ground. If on a knoll, and probably if on a slope, it will be more. A trial location by the diagram and one check computation will enable the elevation to be fixed. If the reservoir is wholly in

excavation, the amount will be found on the diagram by using the depth from the surface to the inside bottom of the reservoir.

SIDE WALLS.

The side walls should be vertical, or nearly so, in order that the vaulting shall have to cover as little area as possible. The ordinary practice in the design of dams or retaining walls is not applicable to these walls. Being supported outside by the earth, they are not like a masonry dam. The thrust of the vaulting resists the tendency of the wall to rotate on its toe; therefore they are unlike retaining walls. If the masonry were homogeneous, the wall of a square or rectangular reservoir would act as a beam, with the roof and floor as supports; but it is improbable that the bonding of the horizontal joints would be sufficiently good to prevent

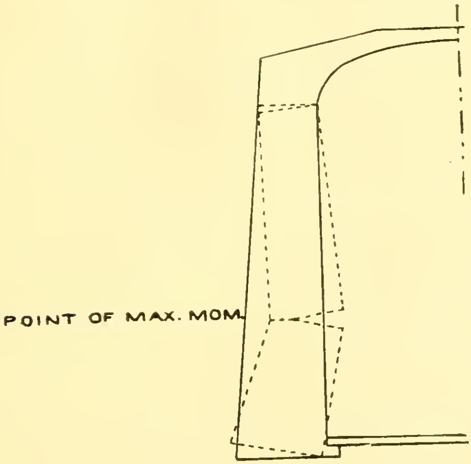


FIG. 5.

failure. When, however, the point of failure is reached, in order for it to proceed a crack or joint must open on the inside of the wall. If the material is assumed to be rigid, either the part of the wall above the break and the load upon it must be raised or the lower portion must be pressed into the earth with a force equal to the load above to allow the crack to open. In this case the moment of the external forces acting upon the wall is resisted by that of the weight into its lever arm.

An examination of Fig. 5 makes it evident that the whole wall must be raised, but, as one edge is supported, only one-half of its weight resists forces tending to lift it; the weight of the half-arch of the roof with its load must also be raised. If it is assumed that

the material is not rigid, but will be crushed or tend to be crushed on the edges on which the two parts rotate, the weight must still be raised; but the lever arm of the weight will be shortened by so much of the thickness of the wall as will sustain the weight above the break without exceeding the strength of the material. In a reservoir that is to be emptied occasionally, the maximum outside pressure on the wall would be that due to water remaining in the earth behind the walls. With a reservoir partly in excavation the height of this water could not exceed the high-water line of that inside, while in one wholly underground it might be at the surface, or even above it, if the site were occasionally flowed. The maximum moment of this pressure, assuming that the water outside is

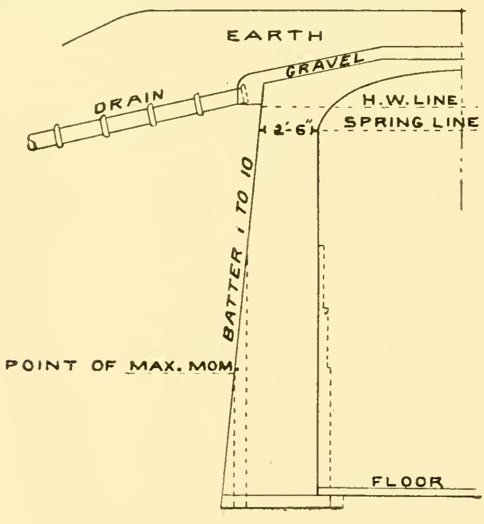


Fig. 6.

at the spring line of the roof arches, is at one-third of the height of the wall from the bottom; its amount in foot-pounds is that due to a load distributed in the form of a triangle, whose base is equal to the height of the wall and whose perpendicular is equal to the height in feet into the weight of water per cubic foot.

The foregoing refers to straight walls only; in the walls of round reservoirs the outside pressure is resisted by the wall as an arch. If this pressure is assumed to be due to the water in the earth backing, it will be uniform all around, and the maximum pressure at any point will not exceed one-half the product of the unit pressure by the diameter. The total pressure will increase with the depth and the diameter until dimensions are reached for which the thickness must equal that for straight walls. For greater dimen-

sions they must be designed to meet the conditions of the latter. The thickness of the top of the wall is not governed by these considerations. The thrust of the roof will largely determine this thickness. On straight walls, as shown in Fig. 6, the horizontal thrust of the roof is approximately 2.25 tons per lineal foot. Neglecting the adhesion of the mortar, there are two factors of resistance to this thrust,—that caused by the friction of the wall and its load on any joint or place in the wall where movement would take place, and that due to the embankment above such joint. With a thickness at the spring line of 2½ feet, as shown in Fig. 6, the sum of these two elements of resistance, above a point in the wall where the resultant pressure of the arch and the wall above this point passes through the outside of the middle third, is about 1.9 times as great as the horizontal thrust of the roof, or a factor of safety of nearly two.

With circular walls in which the groined arch must be carried out to the wall at most points and can be at all, the average horizontal thrust is not so great as in straight ones, being about 1.75 tons per lineal foot. The resistance of the embankment above the spring line is about 2 tons, or 1.15 times the thrust. It is easy to increase this resistance by a ring of steel imbedded in the wall above the spring line; therefore it is not necessary to thicken the wall, as the roof exerts only a vertical pressure upon it. Its thickness will then be determined by the requirements of practical construction; all of these will be met by a thickness of 2 feet at the spring line.

As examples of existing walls with this type of roof, the two following are straight walls. Those of the filter beds at Ashland, Wis., are 2 feet thick at the top, and have a batter of about 1 in 10. These are either wholly in excavation or have an embankment 15 feet wide, supported by a braced pile trestle. The walls of the Albany filters are in embankment, are 2½ feet at the top and have a batter of 1 in 10. For circular walls, those of the Wellesley reservoir are 2 feet thick at the top. The walls of the sewage reservoir at Clinton are to be 2 feet at the top and have a batter of 1 in 10.

A steel ring was imbedded in the walls of the two last-named reservoirs. In the Wellesley reservoir, which was 82 feet in diameter, this ring was made of a channel iron weighing 32 pounds per foot. In the one at Clinton it is to be in three parts or rings of flat iron. The reservoir is 100 feet in diameter, and the total weight of the rings per lineal foot is 30 pounds. This seems to be a better arrangement of the steel than the channel iron, as the joints or splices in the different rings can be "staggered" and loss

of strength in the total section reduced to that in one ring, and it can probably be furnished and placed at a lower rate per pound.

Fig. 7 shows the arrangement of such rings in the section of the wall. The following table gives the required weight for reservoirs of various diameters per lineal foot and the total weight. The weights given are designed to provide a factor of safety of three in the resistance to the thrust of the vaulting, including the resistance of the earth embankment. Note.—In computing the resistance of the embankment and the wall to sliding a co-efficient of friction of 0.80 was taken for earth; of 0.65 for masonry. The weights of the following table are also given on Diagram No. 1, which will give other diameters than those in the table:

TABLE NO. 3.

Weight of Steel Ring.

Diameter in Feet.	Weight in Lbs., per Lineal Foot.	Total Weight in Lbs.
50	14.5	2,280
60	17.4	3,280
70	20.3	4,460
80	23.3	6,850
90	26.2	7,380
100	29.	9,120
125	36.3	14,300
150	43.5	20,600
175	50.8	28,000
200	58.	36,500

Formula for dimensions not in table: Weight per lineal foot = 0.29 Diam. Total weight = 0.912 Diam.^2

In the above table 25 per cent. is allowed for splicing and rivets; therefore, to find the weight of the net cross-section take 80 per cent. of the above weights per lineal foot.

In the construction of the walls satisfactory results can be secured by the use of either concrete or rubble masonry of sound angular stones of any sizes that are not large enough to go entirely through the wall. Exceedingly good work can be done with small stones by laying the face of the wall up to a form and bedding the stone thoroughly in the mortar without regard to bonding, making a coarse concrete in fact. All smooth, rounded stones should either be broken or thrown out. Portland cement should be used for this work, as it should be for all of the work in these reservoirs. Natural cement may, of course, be used, but as strength is required rather than weight the cost of equally satisfactory work will be greater than with Portland cement. The choice of concrete or rubble will probably depend upon the kind of material which is the most available.

Diagram No. 3 gives the amount of masonry in the side walls of square and round reservoirs. This diagram is computed from the sections shown in Figs. 6 and 7, and includes all of the masonry from the under side of the foundation to the extreme top of the wall. "Depth," as before, means depth of water. These sections are sufficient for reservoirs of the dimensions given on the diagram, and are uniform for all. They could perhaps be made lighter for the smaller sizes and depths of the round reservoirs if it was considered desirable to do so. For preliminary estimates it is hardly worth while to make any changes from the quantities given on the diagrams. The following tables give the approximate unit pressures that the maximum outside pressures bring upon the masonry when calculated in the manner already indicated:

Table No. 4.

Straight Walls.

Height of Wall.	Maximum Moment.	Weight of Wall to be Raised.	Necessary Length of Lever Arm.	Thickness of Wall at Point of Max. Moment.	Thickness Remaining to Resist Crushing.	Total Pressure on Masonry.	Max. Unit Press. Tons per Sq. Ft.
Col. 1	2	3	$4=\frac{2}{3}$	5	$6=\frac{5}{4}$	7	$8=\frac{7}{6}$
5 feet....	0.180	2.62	0.07	2.80	2.73	2.40	0.88
10 "	1.50	3.24	0.47	3.20	2.73	2.80	1.03
15 "	4.78	4.10	1.17	3.50	2.33	3.20	1.38
20 "	11.25	4.80	2.35	3.80	1.45	3.80	2.62
25 "	22.00	5.60	3.93	4.20	0.27	4.30	16.00

Table No. 5.

Circular Walls at Depth of 25 Feet.

Diameter.	Total Pressures at Bottom on Section One Foot High.	Cross-Section in Square Feet.	Maximum Unit Pressure per Square Foot.
Col. 1	2	3	$4=\frac{3}{2}$
50................	19.5 tons	4.50	4.33 tons
75................	29.6 "	4.50	6.57 "
100................	39.05 "	4.50	8.67 "
125................	48.80 "	4.50	10.85 "
150................	58.50 "	4.50	13.00 "
200................	78.00 "	4.50	17.35 "

Although the extreme pressures in the tables may be considered rather high for rubble and concrete, it must be remembered that they could only occur if the water in the earth backing remains at the high-water line until the reservoir is wholly emptied. This would be a rare condition in an embankment, and may be avoided entirely if desired. The method of doing this will be referred to hereafter.

The pressure of the water in the reservoir tending to force the wall outward must be resisted by the earth backing, otherwise the wall must be designed as a dam. If this were necessary, all of such

walls that are existing to-day would have failed. If there is a slight yielding in the earth, it is probably compensated by some elasticity in the masonry. It is of the utmost importance, however, that the backing be deposited in very thin layers and thoroughly rammed. If the nature of the excavation is such that it will stand vertically or nearly so until the wall can be built, it is desirable to make the lower part of the latter without batter or offset on the outside to as high a point as possible and to lay the masonry solidly against the undisturbed earth. If the theory of the resistance of straight walls that is adopted in this paper is correct, they may be built with a vertical back from the point of maximum moment (at one-third of their height) to the bottom without loss

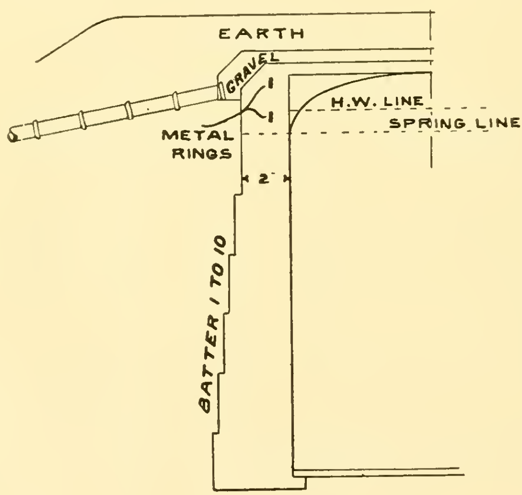


Fig. 7.

of strength. Fig. 4 shows how circular walls may be built to secure a vertical line in the lower part of the wall; there will generally be no objection to the interior offsets, and in filters they are desirable in order to avoid a direct line for the water to follow from top to bottom.

There is one more factor to be considered in the design of straight walls; that is the tendency of the wall to slide into the reservoir. Following the idea that the wall is a loaded beam, the tendency to slide must be met by a reaction at the top equal to one-third of the total load on the wall, and at the bottom to two-thirds. Assuming water pressure at the back as before, the loads and reactions are as follows:

TABLE No. 6.

Reactions at Top and Bottom of Straight Walls.

Height of Wall.	Total Load.	Reaction at Top.	Reaction at Bottom.
5 feet...........	0.39 tons	0.13 tons	0.26 tons
10 "	1.56 "	0.52 "	1.04 "
15 "	3.50 "	1.17 "	2.33 "
20 "	6.23 "	2.08 "	4.15 "
25 "	9.75 "	3.25 "	6.50 "

There are three factors of resistance to sliding at the bottom of a wall such as shown in Fig. 6,—the friction of the wall on the earth, the resistance to compression of the concrete floor and of the earth inside of the foundation under the floor. With a floor 4 inches thick and wall foundation 6 inches deep, with co-efficient of friction of the wall on the earth of 0.65 and safe pressures on the earth and floor concrete of 2½ and 10 tons per square foot, respectively, the total resistance for a unit section 1 foot long is given in Table No. 7:

TABLE No. 7.

Resistance to Sliding of the Bottom of Straight Walls.

Height of Wall.	Friction on Earth.	Resistance of Concrete.	Resistance of Earth.	Total Resistance.	Reaction at Bottom.	Excess of Resistance.
5 feet......	1.76	3.33	1.25	6.34	0.26	6.08 tons
10 "	2.27	3.33	1.25	6.85	1.04	5.81 "
15 "	3.05	3.33	1.25	7.63	2.33	5.30 "
20 "	3.83	3.33	1.25	8.41	4.16	4.25 "
25 "	4.62	3.33	1.25	9.20	6.50	2.70 "

These figures indicate that such walls under 25 feet in height will not fail by sliding at the bottom. They will not fail at the top if the thickness is sufficient to prevent shearing. The reaction at the top of a 25-foot wall is 3.25 tons. The section to be sheared in a wall 2½ feet thick at the top is 360 square inches per lineal foot, or a stress of about 19 pounds per square inch. There are no data on the shearing strength of concrete; it seems, however, that it must be greater than the tensile strength, and that the above must be a safe figure for that of good concrete or rubble in Portland cement. The above stresses only occur in a reservoir that is just emptied.

NOTE.—As the thrust of the vaulting against the wall in the proposed design is but 2.25 tons per lineal foot, if the required reaction at the top must exceed that amount in order to resist the outside pressure, the load on the vaulting must be made heavier and the vaulting stronger to provide the required reaction.

PIERS AND THEIR FOUNDATIONS.

The maximum load upon each pier with the roof shown in Fig. 3 is about 46 tons, the piers being 14 feet apart on centers in

each direction. Piers can be built of either brick or concrete. The great majority of existing piers are of brick, very few of concrete being on record. There seem to be practical reasons for the use of brick. The amount of material is not large, and it is probable that the expense of making and setting forms for concrete will make its cost as great in this class of work.

The allowable unit pressure for Portland cement brickwork is not definitely determined. Baker, in his book on "Masonry Construction," gives about 30 tons per square foot as a general estimate. In a pier, however, the relative dimensions should be considered in its design. There is a wide diversity in practice, as shown by existing examples. The following table gives the dimensions and unit pressures in several modern reservoirs:

Table No. 8.

Dimensions and Pressures on Piers.

	Piers			Roof Surface			Unit Pressure Multiplied
Reservoir.	Height, Feet.	Section, Square Feet.	Cross-Section Divided by the Height.	Area, Square Feet.	Approx. Weight, Tons.	Unit Pressure, Tons.	by Length of Pier.
Newton	13.5	2.78	0.205	136	32.	11.5	155
Brookline	17.5	4.00	.228	144	26.5	6.63	116
Franklin	16.5	1.00	.061	90.5	20	20	330
Ashland	5.0	4.00	.80	248	54	13.5	67.5
Wellesley	12.25	4.00	.325	196	51	12.75	156
Albany	7.5	2.78	.370	187	41	14.75	111
Clinton	7.0	4.00	.572	210	78	19.5	136
Proposed	7.0	2.78	.398	196	46	16.55	·116

The height of piers given in the above table is not in every case the total height from the floor to the spring line, but the length between offsets. The piers in the first three cases had no offsets, but were uniform in size from top to bottom; in all of the others the bases of the piers were enlarged, and in the Clinton reservoir and the proposed design the top is also enlarged by offsets. It is very desirable to spread the base in order to distribute the strains over as large an area of the top of the foundation as possible, so that it may be made thinner and still not overload the earth below. Where the unit pressures are high it is also desirable to spread the top of the piers, so that they may not be so great in the concrete at the spring line. A neat and economical design for piers is to make the body of the same size for all heights, and make the offset portion at the bottom (and at the top if desirable) longer as the total length of the pier increases, keeping the length of the body the same for all heights of reservoir.

Fig. 8 shows a pier of this design. The body of the pier is 20 inches square, and for heights of 8.25 feet and over its length is 7 feet. The base increases in height, but not in bottom area, as the

pier is made longer. Diagram No. 4 gives the amount of brickwork in such piers for different sizes of round and square reservoirs. These quantities are based upon the areas of the reservoirs, and are not precisely correct for some dimensions, but are nearly enough so for preliminary estimates. The following table gives the exact amount for one pier, and, if closer results are desired than the diagram gives, the exact number of piers can be obtained from a plan and the quantities from the table used:

TABLE No. 9.

Brickwork in Piers of Various Heights from Floor to Water Line.

NOTE.—This height is 1 foot greater than the actual length of the pier.

Height of Reservoir.	Brickwork, Cubic Yds.	Height of Reservoir.	Brickwork, Cubic Yds.	Height of Reservoir.	Brickwork, Cubic Yds.
5 feet	0.62	12 feet	1.62	19 feet	3.01
6 "	.72	13 "	1.82	20 "	3.20
7 "	.83	14 "	2.03	21 "	3.40
8 "	.95	15 "	2.24	22 "	3.60
9 "	1.10	16 "	2.45	23 "	3.79
10 "	1.27	17 "	2.64	24 "	3.98
11 "	1.45	18 "	2.83	25 "	4.17

Piers should be built of the best of brick, in respect to the qualities of hardness, homogeneity and uniformity of shape and dimensions. They should be laid with absolutely full joints in Portland cement mortar as closely as the brick can be laid and the joints neatly struck with a jointing tool.

PIER FOUNDATIONS.

Pier foundations should be designed to transmit the pressure from the piers to the earth uniformly, with a unit pressure that is safe for the character of the ground. The following table is taken from Baker's "Masonry Construction":

TABLE No. 10.

Safe Bearing Power of Soils.

Kind of Material.	Tons per Sq. Ft. Minimum.	Maximum.
Clay in thick beds, always dry	4	6
Clay in thick beds, moderately dry	2	4
Clay soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, compact and well cemented	4	6
Sand, clean and dry	2	4
Quicksand, alluvial soils, etc	0.5	1

The soil in most sites of reservoirs for water supplies would be as strong as sand, compact and well cemented, and could be loaded with 4 tons per foot. Sewage reservoirs and filter beds might often

be on less secure foundation. Each case must be considered on its merits. Having determined the horizontal dimensions by reference to the allowable unit pressure on the soil, the depth or thickness of the foundation depends upon its size and that of the bottom of the pier that rests upon it. The thickness will probably be sufficient if a line drawn from the outside edge of the bottom of the pier to the bottom edge of the foundation has a batter of not more than 1 to 2; thus, if the foundation is 6 inches larger each way than the bottom of the pier, its thickness should be not less than 1 foot. With good Portland cement concrete this would distribute the pressure over the entire bottom of the foundation. From Diagram No. 1 the quantities may be taken for the pier foundations

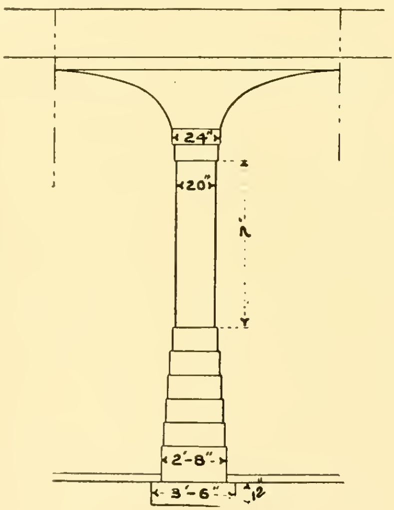


Fig. 8.

shown in Fig. 8, which were designed on the foregoing principles to carry the roof and the load that has been described. The estimated pressure on the soil in this case is about 3.8 tons.

FLOOR.

There should be a smooth concrete floor in all covered reservoirs. Its thickness is dependent upon the conditions of the particular reservoir. If the material in which it is built is such that there is little danger of outward leakage, and there is no likelihood of an upward water pressure to lift the floor when the reservoir is emptied, a thickness of 3 or 4 inches is sufficient. The reservoirs at Brookline, Newton and Wellesley had floors 4 inches thick; the floor of the Ashland filter was 3 inches. If, on the contrary, the

earth is pervious, and the movement of water when the reservoir is full will be away from it, the floor should be at least 6 inches. From his experience in the construction of and subsequent observation of a number of open reservoirs, also from experiments on concrete of different thicknesses, the writer believes that with heads of 20 feet and under 6 inches of good Portland cement concrete is, or becomes in a short time, very effective in preventing seepage. It should be plastered or finished with rich cement mortar. An excellent method for floors is to finish the concrete as soon as it is rammed, before it begins to set, with mortar mixed for the purpose. If a surplus of water stands on the concrete after ramming, good work can be done by spreading dry cement on and working it to a smooth, close surface with trowels. The liability of separation and peeling off which exists in plastering that has been done after the concrete has set is thus avoided.

If, when the reservoir is emptied, there will be an upward pressure on the floor, it must be designed to resist it. For this purpose inverted arches may be used, designed to carry the estimated pressure to the piers. The roof arches may be reversed, or the feet of the piers given a greater spread and flat circular arches used. In designing to resist the upward pressure care must be taken that the weight of the reservoir and its earth covering is greater than that of the water displaced, to avoid flotation when it is empty.

The Clinton reservoir is designed to resist this tendency to float, as it is anticipated that at certain seasons the outside water will stand above the reservoir and its earth covering. The latter is made 4½ feet thick to provide the necessary weight. The floor is a series of inverted arches. Where there is no sanitary objection, drainage can be arranged in such a way that there will be no upward pressure when the reservoir is drawn down. With a thin layer of clean gravel or broken stone, and underdrains if necessary, the water under the floor can be collected in a well, and through a pipe tightly set in the concrete floor be delivered into the reservoir when the pressure in the latter is less than that outside. An inward opening flap or check valve must be placed upon the pipe to prevent a loss of water from the reservoir. If drains were carried up the back of the wall, the pressure on the latter would also be relieved.

This arrangement would be undesirable in a sewage or other reservoir, the contents of which must be pumped or treated, as the amount would be increased by a flow from the outside.

PLASTERING.

To prevent leakage from the reservoir, and to secure a smooth surface that will be easy to clean, the inner face of the side walls should be plastered. The best results can be had with two coats, one of mortar, 2 parts sand to 1 of cement, laid on as thick as it will stay to even up the inequalities of the wall. This coat should not be smoothed. The last coat to be of neat cement $\frac{1}{8}$ to $\frac{1}{4}$ inch thick, thoroughly rubbed on with a trowel and nicely smoothed. If there is an outside pressure from water in the ground, it must be reduced by pumping during the plastering and until it is set. Under such conditions the outside should be plastered, if for any reason it is desirable to permanently exclude the ground water.

Diagram No. 5 gives the number of square yards of the plastering on the walls of reservoirs of different dimensions. The depths for which the diagram is figured is that from the floor to the high-water line.

MISCELLANEOUS ITEMS.

There are a number of items that will vary in different reservoirs. Among these are the piping, gates, manholes, ventilators, ladders and, if an automatic recording gauge is used, a small building and the apparatus itself. The cost of these items will be from 7 to 12 per cent. of the total. Seeding and sodding the top and slopes are included in the above.

TOTAL COST OF RESERVOIRS.

On the diagrams that accompany this paper are given the quantities of the material in the different parts of the reservoirs of the type described in the paper and shown on the sketches. With some of them there is a multiplying diagram by which the cost of such quantities at various prices per unit may be found. With the diagrams an estimate of the quantity of material and the cost of a reservoir of any dimensions within the limits of the diagrams can be readily made that will be correct for this type. A slight change in design, as, for instance, different spacing of the piers or minor changes in the form of the parts, will not materially affect the estimate.

For making preliminary estimates with even less work than the above entails, and for rapidly determining the economic ratio of depth to area for any desired capacity, Diagram No. 6 has been prepared for round reservoirs and No. 7 for square ones. These diagrams give the capacities in gallons and the cost in dollars for all of the dimensions within their limits. They were prepared by

taking the sum of the cost of all of the items at the unit prices given in Table No. 11, and adding 10 per cent. to this sum for the miscellaneous items. The value of this diagram in finding the economic ratio of depth to horizontal dimensions is not limited to this type, as this ratio will be approximately the same for others. It is believed that it will be found useful in preliminary estimates for other types and at other unit prices by applying such corrections as the engineer believes to be necessary.

Table No. 11.

Unit Prices of Quantities in Covered Reservoirs.

Earth excavation	per cubic yard	$0.50
Rubble or concrete in walls, pier foundations and floors	" " "	6.00
Concrete in roof	" " "	6.50
Brickwork in piers	" " "	13.00
Plastering walls	" square "	.25
Plastering floor	" " "	.15
Gravel on roof arches	" cubic "	1.00
Steel ring	per pound in place	.05
Centers, etc.	per square foot for total area of reservoir	.15

Table No. 12 gives the cost of certain capacities of reservoirs when built with economic dimensions. Caution.—As prices have risen materially since Diagrams 6 and 7 were prepared, it is probable that a percentage should be added to the results for present use.

It is perhaps needless to caution the reader against using the designs or the quantities given in the paper unless the conditions are substantially similar to those described, or until proper modifications are made.

Table No. 12.

Cost of Covered Reservoirs when Built with Economic Dimensions.

Capacity. Gallons.	Round Reservoirs. Diam.	Depth.	Cost.	Taken from Diagrams 6 and 7. Square Reservoirs. Diam.	Depth.	Cost.
250,000	60	12	$4,700	54.5	11	$4,800
500,000	75	16	7,800	69.5	14	8,100
750,000	88	17	10,500	79.5	16	11,000
1,000,000	98	18	12,850	88.5	17	13,550
1,250,000	106.5	19	15,200	99.5	17	16,050
1,500,000	115.5	19	17,550	106	18	18,400
1,750,000	120	21	19,950	111.5	19	21,700
2,000,000	125	22	22,000	118.5	19	22,900
2,500,000	134	24	26,200	130	20	27,300
3,000,000	144	25	30,200	142.5	20	31,450
4,000,000	*166	*25	37,900	153.5	23	39,500
5,000,000	*186	*25	45,600	*165	*25	47,400

*These are not the economic dimensions. The diagram does not give greater depths than 25 feet. Moderate departures may be made from the economic dimensions, in either direction, without greatly increasing the cost.

Cost of 1,500,000 Capacity with Different Dimensions.

Gallons.	Diam.	Depth.	Cost.
1,500,000	112	20.5	$37,600
1,500,000	115.5	19	17,550
1,500,000	118	18.5	17,600
1,500,000	150	11.5	19,900

SECTIONAL RESERVOIR COVERING.

On account of the cost of centering for the type of vaulting described in this paper, it has seemed to the writer that it would be desirable if some form of vaulting could be devised in which this

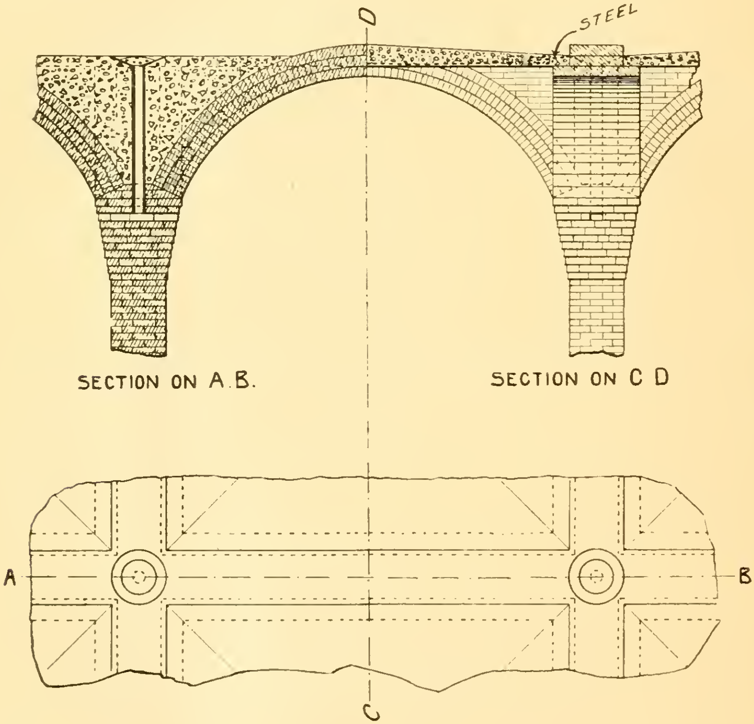
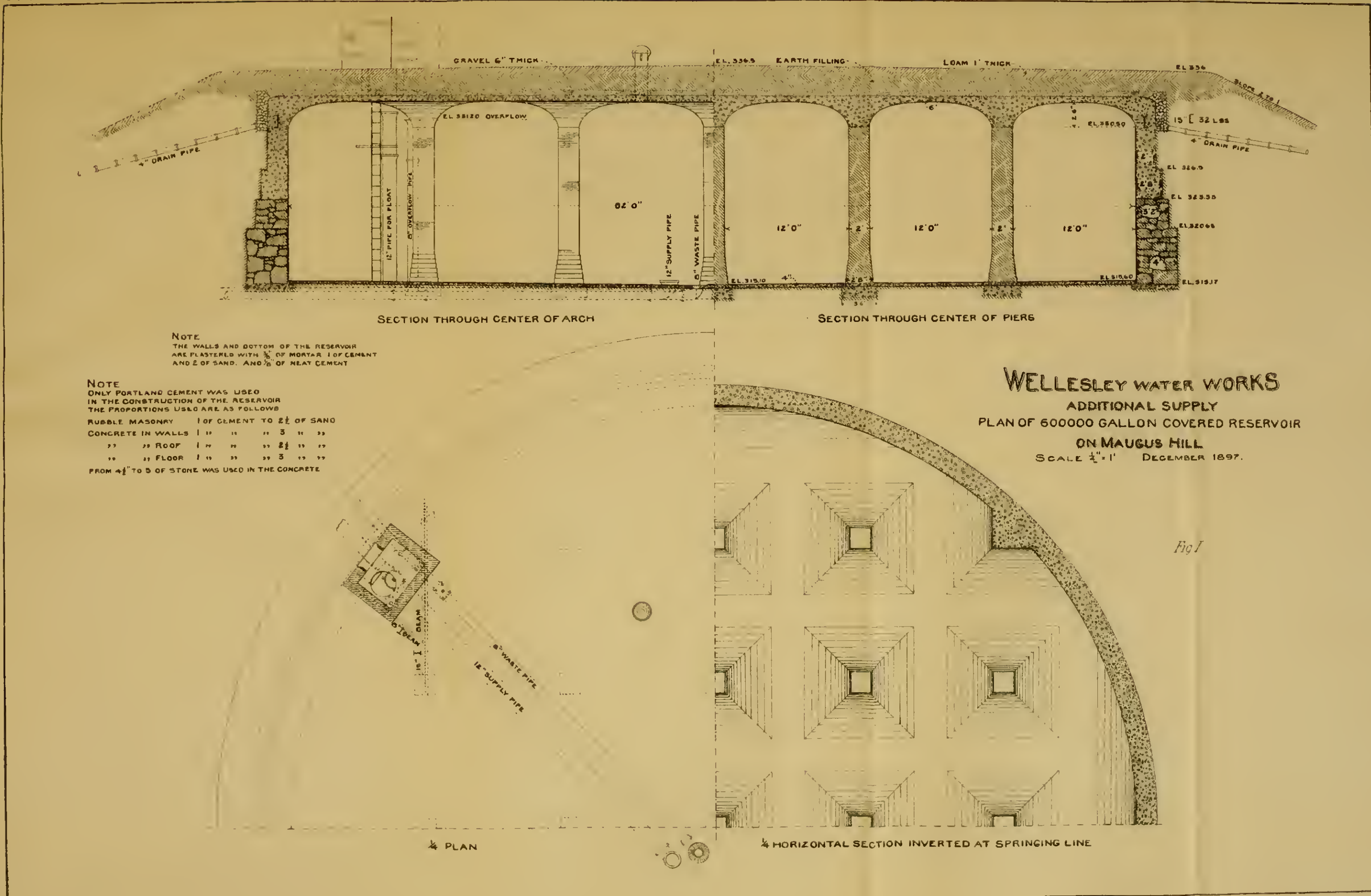


Fig. 9.

cost can be reduced and the advantages of the groined arches retained. The very successful use of a combination of steel and concrete in floors that sustain heavy loads has suggested the adoption of some such type of construction for covering reservoirs. It is undesirable to use in this work steel that cannot be thoroughly imbedded in concrete. For this reason, and because they will cost more than masonry, it is not proposed to support the covering on steel girders, as the floors are supported. It is proposed to build brick piers spaced the same as for the groined arches, and from

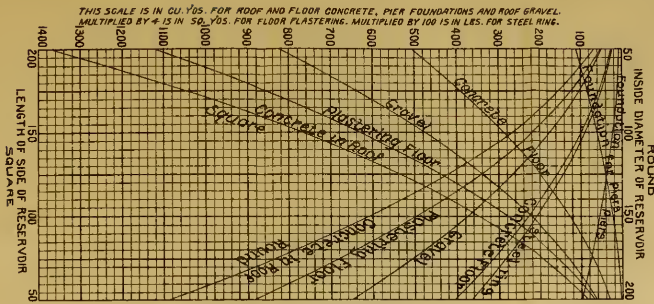

GRAVEL 6" THICK
EARTH FILLING
LOAM 1' THICK
EL. 336.5
EL. 336
4" DRAIN PIPE
15" [32 LBS
EL. 331.20 OVERFLOW
EL. 330.50
EL. 326.5
EL. 323.35
EL. 320.65
EL. 315.17
EL. 315.10
EL. 315.60
12" PIPE FOR FLOAT
8" OVERFLOW PIPE
12" SUPPLY PIPE
8" WASTE PIPE
82' 0"
12' 0"
12' 0"
12' 0"
SECTION THROUGH CENTER OF ARCH
SECTION THROUGH CENTER OF PIERS
NOTE
THE WALLS AND BOTTOM OF THE RESERVOIR
ARE PLASTERED WITH ⅜" OF MORTAR 1 OF CEMENT
AND 2 OF SAND. AND ⅛" OF NEAT CEMENT
NOTE
ONLY PORTLAND CEMENT WAS USED
IN THE CONSTRUCTION OF THE RESERVOIR
THE PROPORTIONS USED ARE AS FOLLOWS
RUBBLE MASONRY 1 OF CEMENT TO 2½ OF SAND
CONCRETE IN WALLS 1 " " " 3 " "
" " ROOF 1 " " " 2½ " "
" " FLOOR 1 " " " 3 " "
FROM 4½" TO 5 OF STONE WAS USED IN THE CONCRETE
WELLESLEY WATER WORKS
ADDITIONAL SUPPLY
PLAN OF 600000 GALLON COVERED RESERVOIR
ON MAUGUS HILL
SCALE ⅛"=1' DECEMBER 1897.
Fig I
8" WASTE PIPE
12" SUPPLY PIPE
¼ PLAN
¼ HORIZONTAL SECTION INVERTED AT SPRINGING LINE

G
1,5
1,5
1,5
1,5

de
de

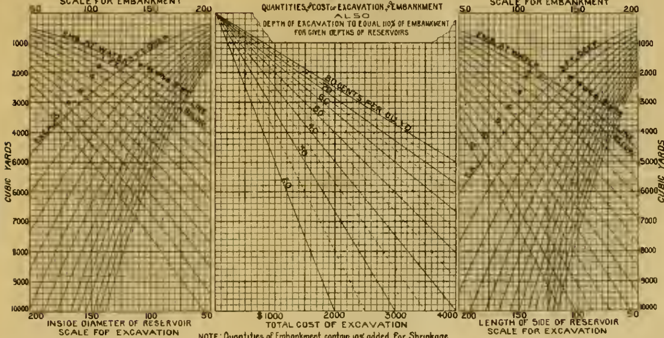
A

cos
ret
con
tio
is
imb
mo
stee
bric



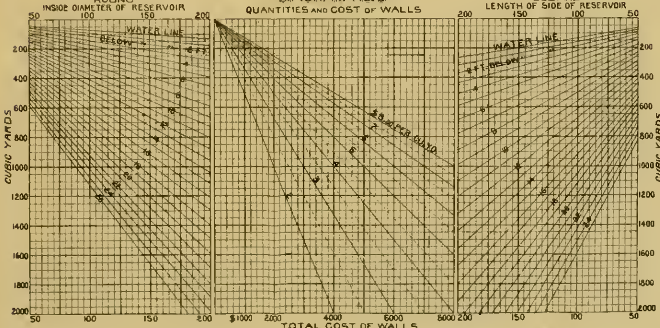
NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIRS
" " "BOTTOM" SQUARE "

COVERED RESERVOIRS
DIAGRAM NO. 1



COVERED RESERVOIRS
DIAGRAM NO. 2

NOTE: Quantities of Embankment contain 10% added for Shrinkage



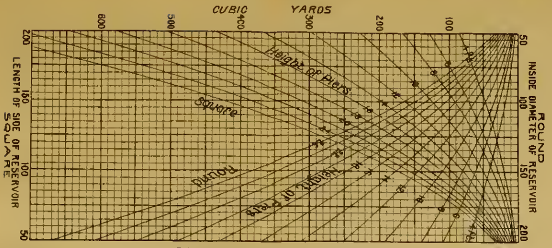
COVERED RESERVOIRS
DIAGRAM NO. 3

G
1,5
1,5
1,5
1,5

de
de

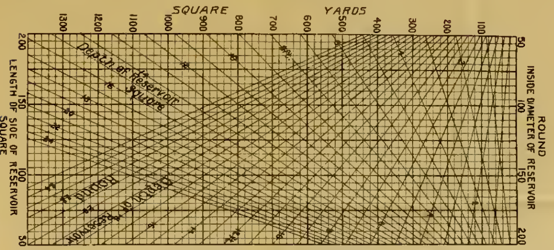
A

cos
ret
con
tio
is
imb
mo
stee
bric



NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIRS
" " "BOTTOM" SQUARE "

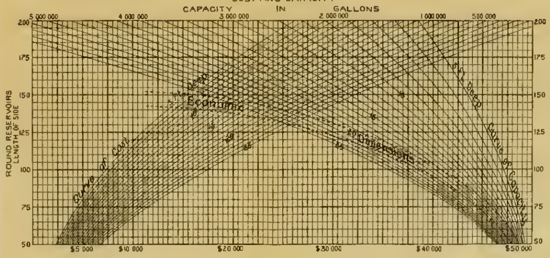
COVERED RESERVOIRS
DIAGRAM NO. 4
BRICK PIERS



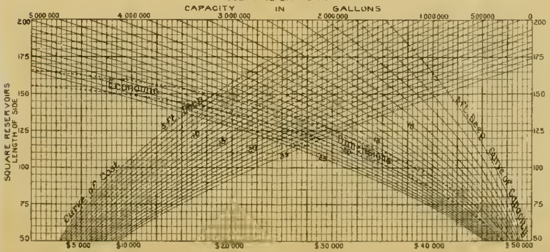
NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIR
" " "BOTTOM" SQUARE "

COVERED RESERVOIRS
DIAGRAM NO. 5
PLASTERING INSIDE FACE OF WALLS

COVERED RESERVOIRS
DIAGRAM NO. 6
COST AND CAPACITY



COVERED RESERVOIRS
DIAGRAM NO. 7
COST AND CAPACITY



G
1,5
1,5
1,5
1,5

de
de

A

cos
ret
cor
tio
is
iml
mo
ste
bri

these piers spring brick arches each way, as shown in Fig. 9. These arches will support a slab of the steel-concrete, as shown in the figure.

The advantages to be secured in the construction of this type are that simple circular centers can be used for the brick cross-arches, and only enough of them will be necessary at one time to build one line across the reservoir, as there is no diagonal thrust caused by the arches. The centers, or rather forms for the covering slab, will be simply a plain flat surface; as many or as few of them may be prepared as may be required for the proper rate of prosecution of the work. The best of work can be secured in the slabs, as they are made independently of each other and can be finished before the concrete is set; therefore with a perfect bond throughout.

This type of covering will give practically the same head room and arrangement for ventilation as the groined arches, and will, I believe, be cheaper and less troublesome to build. The thickness shown in Fig. 9 is not to be assumed as correct. No computation has yet been made to ascertain this correctly. One of the companies that supply the metal for this construction, in answer to an inquiry, stated that it was probable that under the named conditions No. 4 gauge metal and 6 inches of concrete would carry 300 pounds per square foot, but advised the writer to make the computations himself. He had already found that the distinguished mathematician St. Venant has said that the problem of the strength of a square slab supported at its four edges is incapable of solution, and has therefore not yet made the computation. Experiment is the proper method of determining the safe thickness, and fortunately, if it should be desirable to build this form, such experiments on full-size test pieces in place could be readily made. Lacking such knowledge, it has not seemed advisable to make any estimates of the cost for comparison with that of other types.

FIELD NOTES OF A CIVIL ENGINEER.—DO THEY BELONG TO HIS CLIENT OR TO HIMSELF?

By J. Vander Hoek.

[Read at the regular monthly meeting of the Engineers' Society of Western New York, Buffalo, N. Y., October 7, 1895.]

Mr. Chairman and Gentlemen: When I was asked by a member of the Topic Committee of this Society to prepare a paper on the question, whether the field notes of a civil engineer belong to his client or to himself, I had never given this matter any serious consideration. During the few years of my practical experience in civil engineering in this country I have never been placed in a position where it appeared to me that the private ownership of the field notes which I took could be of any benefit to me. For this reason I am not able to speak on this subject with the fuller knowledge of one who has often been interested in this question and whose opinion has been matured by the discussion of the various features of cases which have presented themselves to him in practical life. I have, nevertheless, accepted the invitation and prepared this paper, because I consider the topic well worthy of attention, and also because it appears to me that this question may perhaps be introduced with more freedom by a member who has been placed thus far outside the general engineering practice and who is not concerned, except in a general way, in the conclusion of the argument.

It will not surprise you, after receiving this communication, that I have been obliged to build up an opinion by considerations of a theoretical rather than of a practical nature, and that I have made use of actual and fancied cases only to make clear and to test the correctness of the rulings.

Before entering upon this part, I wish first to say something to define the word "field notes." Field notes may be said to refer to all data that are taken in the field, for the purpose of describing the conditions of the field, or of describing the location of objects on the field. These data are noted down in books on the ground and form what are commonly called "the original field notes." Copies of these original field notes are sometimes prepared and known as "copies of field notes." I intend to use these names in this paper to distinguish their limited meaning from the more comprehensive sense of the word "field notes," which includes also the information contained in these notes,—that is, the knowledge of which the notes are the memoranda. While the original field

notes and copied field notes refer to books, the word "field notes," in its fullest sense, stands for the information itself and has an abstract meaning.

I have made this distinction to show that while the original field notes, being tangible objects, can as such be the subject of a dispute of ownership in law, the information which they contain is something too subtle to admit of the enforcement of court decisions. For so far as the question refers to the note books, we should go to the common law for advice, and so far it forms more properly a topic in a lawyers' debating club than in an engineers' society. But if we consider it with the word "field notes" taken in its broader meaning, the issue cannot any more be decided in the courts, and may best be discussed by members of our profession. I wish here to call attention to the fact that inasmuch as the field notes are nothing else than the memoranda of certain information, it must follow that the party who is found to be entitled to the ownership of this information is also entitled to the possession of the notes.

In formulating the question, the word "client" has been used, although this word, properly speaking, refers only to a person who applies to a lawyer for legal advice. I suppose that the word client has been preferred to the word employer in order to bar from the discussion all such cases where the engineer is in the position of a regular employe. Allow me, however, to consider also such cases, because I think that there are many engagements which place the engineer, although conducting a general practice, into a position similar to that of an employe. Moreover, the relation between the employer and the employe is a very simple one, and the features thereof are well understood, so that a study of the question under the conditions of this class affords the opportunity to point out some fundamental principles.

I have found it most expedient to divide the cases of various relationship which may exist between civil engineers and their employers and clients into two classes, and to consider the question under the different conditions of each class separately. The particular feature of the first class is that the engineer is paid for all he does, while in the cases of the second class the engineer is not paid for his work, but for the product or result of his work. In the first class he is paid by time, in the second by piece.

I wish now to consider our question under the conditions of the first class; two typical cases have suggested themselves to me, namely:

(1.) The engineer is a regular employe and receives a salary.

(2.) The engineer has a general practice and charges by time.

Referring to the engineer as an employe, I would say that he agrees to work steadily and exclusively for his employer, and to devote all his time to his employer's interest. He cannot properly work for another party without the consent of his employer. He receives in compensation a regular salary, which he accepts in full payment of all services rendered during the period of time for which the salary is paid. Considering our question under these circumstances, I would say that the common law governing the ownership of the products of labor, performed by employes on the time of their employer, does not leave room for any difference of opinion as to whom the original field notes belong. I do not think that there can be any dispute of this point, as whatever the employe produces in the time of the employer is the property of the employer. As to the right of employes to copy the notes in their own time for their own benefit, I would say that they have no such right, because the employer has not only paid for the work of writing down the notes, but for the work of obtaining the information, and, therefore, this information itself properly belongs to the employer as well as the notes.

However, the engineer does, as a matter of course, gain more or less information while he is engaged in gathering the field notes, whether he wishes or not; and while the employer may refuse his employe the privilege of preparing copies of the notes, which he has taken, for private use, he can certainly not take away from him the knowledge which he has acquired. The question now comes up whether an engineer working under such conditions has a right to make notes from memory for private use.

I take leave to give in this connection a few lines taken from the issue of *Engineering News*, dated March 22, 1894:

"In a late issue of the *Troy Polytechnic* Prof. W. S. Raymond answers another writer in the same journal, who, in the course of a paper, noted that a certain civil engineer discharged his best assistant for keeping a private note book. This engineer explained his action on the ground that these notes of survey were the private property of the chief; that they were valuable to him as a guide in making future surveys, and hence were decreased in value by duplication. Mr. Raymond suggests the desirability of presenting another side of the question, which, he believes, is more correct in principle, as follows:

"Mr. Raymond believes the young assistant is entirely justified in recalling at night the work of the day and in making notes of it.

He does not use his employer's time in field or office, and as he gains in experience he becomes more valuable to his employer. In fact, a part of his salary is this experience, which is practically the knowledge he gains of certain methods and of the locality in which he works. If he uses his employer's time, however, in making his notes, he is obviously doing wrong, though he is following an example constantly before him."

Allow me to say that in my opinion the side presented by Mr. Raymond is not correct in principle. Although I gladly concede the right of every man to prepare memoranda of his day's work and of whatever appears of interest to him, I do not think that he can consider the information so collected as his private property. He should never lose sight of the fact that these memoranda were made while he was in a position of confidence, and that he gathered the data while in the discharge of his professional duties. Information obtained under such circumstances should not be used without having due regards for the interest of the party who paid for the work. From a practical standpoint no one can dispute that this information belongs to him, but from a moral standpoint I would say that it is not owned, but, so to say, held in trust, by him.

I wish to give one example in support of what I have said and to select a strong one in order to present the points at issue as clearly as possible.

Suppose a railroad company employs a civil engineer for the purpose of finding a route through a very difficult piece of country and spends large sums of money in extensive surveying in order to secure the very best location, or perhaps the only feasible one. A second railroad company, as is not unfrequently the case in this country, desires to construct a line through the same territory, but has no surveyors in the field. Under such circumstances the information gathered by this engineer is not only very valuable to the first railroad company, but equally valuable to the second one. The company who pays will therefore not only exercise its right to the original field notes, but has good reason for refusing the duplicating of the notes. It can, however, only protect itself for so far as the actual notes are concerned. The engineer of the party acquires after many surveys more or less complete knowledge of the country examined, and can, without referring to note books, point out to the second company the best or only feasible location. Can he now consider this knowledge as his private property? If so, he should have a right to do with it as he pleases. I do not know whether the common law would stand in the way if this

engineer saw fit to offer his information for sale to the rival company, but all honest men will agree that in so disposing of his private notes he would place himself on one line with a common cheat. In this case we find that the engineer has no right to dispose of this information, and for that reason it cannot be said to be his property.

I will admit that in the general run of engineering work the information collected during its consummation is not of much benefit, except to the party who paid for it, and that, therefore, the exclusive possession of it is not considered of importance. Neither do I think it necessary for an employer to prohibit his engineer to take copies of notes, except in special cases; but where there is here a question of right to be answered, I would say that the importance of the possible consequences does not alter the principle involved.

The knowledge that comes to the engineer while doing work for others becomes part of him in the same way as a lawyer becomes acquainted with the legal situation of his client, and as the physician learns the physical infirmities of his patients. Neither of them actually own this knowledge, and they are at liberty to make use of the notes for such purposes only as are in the interest of the client and the patient, or in the general interest of their profession.

The large body of subordinate engineers who are employed as assistants to chief engineers come under this class, and I suppose that we all agree that a civil engineer, placed in such a position, should be faithful and loyal to his superior, and that the chief has a right to expect that his assistant shall treat as confidential all important information that may come to him in the performance of his duties. That, as a matter of fact, many employes do consider information obtained during the work as their property is, I suppose, due to a large extent to the neglect of their employer to exercise his right. Sometimes the employe is allowed to consider himself as the sole owner of the field notes by the lack of interest taken by his employer, and this accounts for the strange notions which are found in the heads of some employes.

I wish to cite here again from *Engineering News* for an illustration:

"As a case in point, though not exactly connected with the class of employes here dealt with, the editor is reminded of a bit of experience of a one-time chief of the water department of one of our largest cities.

"This chief succeeded to an office practically devoid of all

records of work performed, and he was forced to have complete re-surveys made of the much scattered property, buildings, reservoirs, etc., under his control. The engineer charged with surveying the reservoir finished the work above ground with little difficulty, but there was a chain of reservoirs connected by a very complicated system of buried pipes and gates, and it was absolutely necessary for the completeness of the work that this connecting system should be accurately mapped. But here he met an obstacle in the form of reservoir keepers, who had held their offices throughout all changing administrations simply because they, and they alone, knew where the pipes, gates and stops were located, and how they were connected with the city system. These keepers positively refused to give away this private information, and there was a halt in the survey. The chief, however, was equal to the emergency, and, sending for the keeper of one of the smallest reservoirs, he personally requested that he point out to his engineers all this underground plant. The keeper again refused to comply, and, somewhat to his surprise, he was discharged upon the spot. The next morning a gang of laborers appeared at the reservoir, formerly in charge of this keeper, and a trench was cut clear around it; every pipe was uncovered and followed to its connection or stop, and a complete survey was then made and mapped. It is hardly necessary to state that there was a sudden change of heart among the other keepers, and the engineer in charge of surveys had little further trouble in getting all the information he needed."

It seems to me that the blame in this example rests more with the engineers who constructed the water works than with the gate keepers; and it has been given for the purpose of showing with what undesirable results the employer might be confronted if he should have to depend upon employes who consider as private property the knowledge which they gain in the discharge of their duties.

I now wish to consider other cases of this same class, but of the second type, which refers to engineers who are not in the position of an employe, but are conducting a general practice. They render services and do work for various parties who call upon them for that purpose, and charge their employers or clients fees, dependent upon the amount of labor involved, or on the importance of the services rendered. Although there may exist an understanding as to the amount of the fee, per day or per hour of labor, there is no agreement as to the amount of the final bill. In other words, the engineer, to use a contractor's expression, charges for the work by force account. I would say that although the very

highest kind of engineering services belong to this group, from a legal standpoint the conditions existing here are very much the same as those under which a regular employe is engaged. It is true the engineer is not expected to devote all his time to the work of this one client; a man in general practice is understood to divide his attention between several matters. But the important point which, I think, rules here is that the agreement provides that the client shall pay for all the time and labor involved and, for that reason, is entitled to all the results of the work. The engineer employed in this manner is only in so far differently situated from a regular employe that he is in a larger measure independent, but this does not confer any more rights to the results of his work than a permanent employe has.

I can readily see that in actual life the engineer keeps the field notes, guided by the idea that they are more valuable to him than to the client, and also because he feels that he will take better care of them than the client himself. Moreover, the field notes of one piece of work may be very helpful in the study of another one in the same neighborhood, and in this way do increased service. But these considerations are all based on convenience, and do not establish any owner's rights. If the client does not claim the field notes, all is good and well, but in case he insists upon having them, I think that justice and the law are on his side.

Suppose, for instance, that the engineer, who has entered into an engagement of this type, should die while the work is in progress, and that already a large amount of field notes have been collected, the possession of which is necessary for carrying on the work. I do not doubt but that we all agree that, under such circumstances, the client should have the right to take possession of the notes upon payment of their cost. Yet the death of the engineer does not in any way diminish his rights, and if the notes properly belonged to him while alive they could not have been claimed by the client after his death.

There are a good many other cases where the field notes are very valuable to the client. I give below a few instances which cover the most important conditions:

Whenever an engineer is called upon to make a survey for a map which is to be on a small scale, as, for instance, a topographical map of a section of the country, he is unable to make his map show all the details as clearly and precisely as the field notes will afford. Generally speaking, the precision of a survey should not be any greater than required for the accurate mapping to a given scale, but in many cases it is more convenient to measure the

topography with greater precision than can be represented on the map.

The field notes have, on account of this additional information, considerable value. Besides, the notes are absolutely necessary when the time comes for making alterations to and corrections on the map. It seems evident that the client who pays the engineer for making such a map should receive all the field notes with the map.

I wish also to call your attention to surveys of lines and objects which are subject to changes by natural forces and where it may be important to use the field notes for precise relocation of objects afterwards.

For instance, in all cases where improvements are proposed which may interfere with the flow of water in rivers and streams, or change the stage of water, etc., a complete set of field notes is very important to the client, because in after times some one may come to the front with a claim for damages alleged to have been caused by the works. The original field notes will then give evidence as to the situation before the improvements were carried out.

A very common case where field notes are of the greatest importance to the client is when they refer to contract work and are to be used for calculating the quantities which are to form the basis of settlement between the contractor and the client.

Last, not least, I would call attention to those cases where an engineer has charge of the engineering in relation to municipal improvements, which require for their maintenance a full knowledge of their construction. I wish here to refer especially to sewerage systems, water works plants, laying out and grading of streets. Although from a legal standpoint it seems to need no argument that an engineer engaged upon such work and charging his client for all the work that he has done has no right to the field notes, yet it is not a difficult matter to cite cases where the engineer has claimed all the notes as his own.

I will cite here one case given in an editorial of *Engineering News*, dated July 14, 1892, in the form of an answer received from a city engineer in response to a request for information regarding the sewerage system of a city with more than 30,000 inhabitants, which is as follows:

"I am unable at present to fill up the blank you sent me. I have been in this office only one year, and my predecessor has been here twenty-six years. When he left he claimed the few records he had kept as his own, and he left me very little more than the bare

walls of the office. He has a book containing the record of sewers now in use, which he offered to sell to the city, but the Council refused to buy, as they feel it should belong to the city by right. I think they will soon decide that the cheapest way to get it will be to buy it, and I will then let you know what it contains. As there were no records or notes of any kind in the office, except a record of street grades, I have not been able to make much headway during the year. I hope to get affairs in shape soon so that the records from this office can take their place with those of any other well-conducted office."

It is apparent that the law does not make itself felt strong enough to impress everybody with the necessity to keep on the right side of it. I have not been able to find any legal decisions directly bearing on this question. This, I think, is more due to the fact that most clients have no adequate idea of the importance of the notes, and consequently do not care about them when it is the proper time to ask for them, than because there is no law to sustain their rights. However this may be, there is in addition to the written law of the land an unwritten one of honor, of which no engineer can afford to disregard the precepts if he desires to practice successfully in his profession. The relation of the engineer to his client, especially where the engineer is invested with the authority to use his own judgment as to the amount of work necessary for the successful completion of the work on hand and where he charges accordingly, he occupies a position of great confidence and responsibility, and he cannot be said to serve his clients well if he does not supply them with all the data and information that may have to be referred to afterwards for the operation or in the maintenance of the completed work. The engineer should assume somewhat the same relation to the client as an attorney, and take full charge of the client's interests as if they were his own, and if the client is not able to appreciate whether the services rendered are more or less complete, the engineer should feel an increased necessity of protecting his client and not take advantage of his inexperience.

It is proper in this connection to quote from the address which Mr. S. Whinery, M. Am. Soc. C. E., former President of the Cincinnati Engineers' Club, delivered at the annual meeting of December 15, 1892.

Speaking of the engineer's duty to his client relative to chief engineers reporting directly to corporations or those engineers who have a general engineering practice and who charge their clients fees dependent upon the labor involved or the importance of the services rendered, Mr. Whinery says:

"When an engineer undertakes to do certain professional work for a client or employer, it is obviously his duty to devote himself to the interests of that client with conscientious zeal and fidelity. His personal interests or affairs cannot be allowed to stand in the way of loyal devotion to the interests of his client. The only exception to this rule is where the demands or the interests of the client conflict with the engineer's sense of right and wrong."

Basing himself on this principle, Mr. Whinery gives the following answer to this question: To what extent do the facts acquired and the results reached in professional work belong to the client for whom the work is done and to what extent do they become the property of, or can they be made use of by, the engineer? The answer is:

"It would seem clear without argument that all the original notes, maps or plans and information, as well as the final result or report, are the property of the client, who pays for having the work done, unless there is a previous understanding to the contrary. There is, however, no reason why the engineer should not retain copies of such documents as a part of his stock of knowledge and engineering equipment for other work. The information thus collected and preserved may be of great assistance to him in future engagements, and it may sometimes become important as a means of defending his personal character. The privilege of using information acquired in the services of a client is subject to one condition that no honorable engineer will violate. Such records and facts cannot be used to oppose in any way the business interests of the client for whom the original work was done."

I would say that this answer deals fairly with the question at issue, because it secures for the client and also for the engineer the largest measure of benefit without harm to any one. It is reasonable and just that the engineer should retain copies of notes for his own protection in case afterwards the quality of his work should be called in question. A good example of such a case was furnished by Mr. Cummings in the meeting of the Montana Society of Civil Engineers in the month of April, 1894:

"An engineer in that State is often called upon to run some important connection lines in the mines, and the execution of the work after it is laid out devolves upon the mine superintendent or foreman. If he should fail to follow the engineer's lines and instructions the work when completed might not connect, and the engineer would be liable for an action for damages. If he had parted with his original notes he would have nothing to show that his work had been correctly done and where the fault really lays."

I take leave to say here that in the same meeting the opinion of those present was that the employer was entitled to all the notes and information obtained from any survey, but that the engineer making the notes ought to have the right to retain either the original notes or a copy of the same whenever he considered them of importance for future use, provided they were not used to the detriment of his employer's interest.

Let us now leave off the discussion of our question as related to time work and enter upon the study of cases of the second class, where the engineer is doing piece work. The characteristic feature of the relation between the engineer and his client under these circumstances is that a certain amount of work is to be performed, the compensation for which is not to be measured by the time involved nor the necessary labor, but solely by the results obtained. Generally speaking, the parties enter into a contract by which the client agrees to pay a certain sum, in consideration of which the engineer agrees to produce certain results.

Referring to these cases, I would say that from a legal point of view there can be no other obligation on the part of the engineer than to comply with the terms of the contract. I do not think that under the circumstances the client can have a legal right to anything else than what he has contracted for. The understanding is involved that the engineer is not going to be paid for his time, and is to have no claim upon the client for compensation until these results have been delivered. A part performance of the contract does not entitle him to a proportionate part of the compensation, and he can recover nothing until all the work is done. Only when the failure to complete the work or perform the contract in full is not the fault of the party who has agreed to do it, or if he has been wrongfully prevented by the other party from completing the work, is he entitled for what he has done. On the other side, if the engineer fails to perform his part of the contract he cannot be compelled to perform the contract against his will, but only damages can be recovered for his refusal unless there be no adequate remedy at law in money or damages. If, therefore, the contract calls for a map, a plan or a report, which is to be prepared by the engineer, the client has no right to anything besides this map, plan or report. The engineer is not paid for his labor, but for the map, plan or report, and whatever additional fruits his labor may have had belong to himself. For this reason I think that the original field notes belong to the engineer, unless the contract provides otherwise.

It is probably on account of such considerations that many contracts entered into between corporations or parties, who desire to

possess the field notes, contain a special provision to that effect. The contract between the village of Batavia and the engineer who has charge of the execution of a sewerage plan for that corporation provides that the field notes shall be turned over to the village authorities.

I understand that the contract relative to the re-surveying of property lines between the city of Rochester and the engineer stipulates that he is to furnish the city with a correct copy of all field notes.

Another example of which I know is in connection with the sewerage work of the village of Charlotte. Also there the field notes were to be the property of the village. I do not know of any contracts where objections were made to the preparing and keeping of copies of the notes. In other specifications for engineering work no special reference is made to the ownership of the notes, but the plans and maps are required to show practically all the information that is contained in the field notes. It appears to me that, wherever this is practicable, this is a very desirable way of getting the benefit of the notes, because the data in such form are at once indexed and ready for reference in the most convenient manner.

Having concluded above that the original field notes belong to the engineer where the engineer is paid for results, I beg leave to add here that this ruling does not end the matter. The question only takes another form, and now presents itself as follows: to what extent should the engineer impart the information of the field notes to his client? It is, as a matter of course, a difficult one to answer, except in a general way, as every piece of work has its special requirements. It would certainly seem advisable wherever engineering work is given out by the piece that a definite understanding be first reached between the parties, so that no room be left for personal interpretations.

There occur in actual life, however, a number of cases where the whole question is carelessly left to the discretion of the engineer, and I am sorry to be obliged to say that there are many instances on record where the engineer purposely kept to himself the information which was necessary to render his work complete, in order thereby to secure additional employment. Allow me to cite a letter, which appeared in the number of *Engineering News* of April 19, 1894, on this subject:

"I am at present engaged on a piece of work where the lack of notes is particularly aggravated. The engineers who make the land surveys in a certain town but a few miles from New York charge by the lump sum for each piece of work. Recently some

differences of opinion arose between the authorities and some property owners regarding a certain street, of which the grading had just been completed. I was engaged by one of the property owners to investigate the question, and on applying at the proper offices was informed that all notes, cross-sections and detail material were the private property of the engineers and could not be seen. Nothing was on file but the profile of the center line of the street in question, and that gave exceedingly meager information. It was not until legal proceedings were suggested that the engineers consented to allow a copy of the notes to be made.

"The same men are not only the engineers for the town spoken of, but also for a city of considerable size. As I happen to live in the town, these things became a matter of considerable interest, and upon investigation I find that, though the entire town has been monumented at public expense and mapped, there is nothing on record showing that there are any monuments, let alone giving their location or references. Much work has been done of which there are not even plans, though ample fees have been paid for the work to cover the most complete records.

"The entire engineering records are in the same shape. The excuse is now offered that 'it has not been the custom of engineers to file the notes or other data,' neither does it seem to have been their custom to file complete plans or maps.

"In this case the sole object sought for seems to be to impress the authorities more with the appearance of the maps and profiles than with their value, as the lettering is very well done and quite conspicuous, and from appearances it would seem that more time has been spent on the titles than on the rest of the work. While neat work is always creditable and always to be desired, fancy lettering at the expense of valuable data is a waste.

"It seems to me that if your paper would continue to agitate the question, and if reputable engineers would take up the matter in earnest, much good might be accomplished. Engineers who are guilty of such practices, it seems to me, should be shunned by their fellow-members of the profession. I would suggest that some good could be accomplished by making such practices a cause of expulsion from membership in the various engineering societies throughout the country."

Although I do not wish to take up the war cry of the author of this letter, I am bound to admit that the principle for which he stands is correct, and I would consider this paper incomplete if no reference was made to the undesirable effects which the practice of reserving notes of land surveys as private, exclusive property

of the engineer has had upon the preservation of important property lines. The purpose of the offices of the County Clerks, established for the recording of all information relative to land properties, has to some extent been defeated by the meaningless descriptions and plats which are found in the files, and which render the work of locating some property lines equal to the solving of a Chinese puzzle.

The engineering profession cannot free itself of all blame in allowing this state of affairs to exist, because, although it has not the power to place the surveys of this country on a firmer basis, it must be admitted that the practices of some surveyors, to keep the field notes of surveys carefully to themselves and to furnish maps and descriptions with the least possible information thereon, has largely increased the difficulty of relocating important property lines. I would add that this practice cannot be considered as in the interest of the engineering profession, and must have the tendency of lowering its standard among other professions and in the community at large. I have seen this summer in the hands of attorneys, representing neighboring property owners, plats prepared by professional surveyors showing the location of the dividing line between these properties thirty feet apart. They are located in the dock section of this city, and where land is very valuable. Several months have passed since, and, so far as I know, no location has as yet been made, so that it will be necessary to compromise. Is it a wonder that the public has no high estimation of the surveying business? Such a condition of affairs could not have come about if each engineer had done his work faithfully and fully, and is largely due to the practice of furnishing plats and descriptions of land without the necessary information for re-establishing the boundary lines. I would say that although the contract may not require him to turn over the field notes to his client, yet the engineer is under the obligation to complete his work, and any map or plat which does not contain sufficient data to enable any surveyor to relocate the property and to ascertain its location with reference to abutting properties cannot be said to be complete. This question has been fully discussed in the editorial of *Engineering News* of March 29 of last year, from which I beg leave to copy:

Mr. Raymond says that the question of what constitutes a survey arises at once in this discussion, and the answer must depend upon the object of the survey. Surveys for subdivisions of large tracts, or surveys intended for establishing the boundaries of a known tract, or for determining a description when the boundaries are known, are alone considered here. The principle enunciated applies, however, to any survey.

"A survey is the operation of finding the contour, dimensions, position or other particulars of any part of the earth's surface, and representing the same on paper. The setting of corners, or monuments, and their description becomes a part of the survey, and the maps, together with the notes, should show faithfully the ground, the work done and the items mentioned. The purpose of establishing corners or monuments is to mark on the ground the boundaries of tracts, to plainly define the location with reference to other tracts and to enable future surveyors to correctly trace the boundaries. The survey is evidently not complete until the corners are fixed, proper information obtained and the same put into the maps and into the notes.

"The doing of all this constitutes a survey, and the question now is to whom does this survey belong? Mr. Raymond believes it belongs to the individual who pays for it, and it is hard to see how these surveys, or any part of them, can become the sole property of the surveyor. The latter may keep notes to facilitate his future work, but he cannot properly claim a single note made in the time paid for by his employer.

"If, however, the surveyor takes the work not on time, but for a definite sum for the entire job, he may take as much time and as many private notes as he likes. But, as he is bound in honor to return to his employers the survey complete in every detail, it is not obvious that his private notes would be of great assistance to him in securing further work, especially when it is remembered that professional men of repute do not bid against each other for such work. His reputation for accuracy and honesty will be worth much more than any quantity of private notes.

"The records of monuments and street lines made by a city engineer are no more his private property than are the records of the city clerk, auditor or treasurer. Court decisions indicate the correctness of the position here taken, though much laxity is shown in this respect by city engineers and county surveyors. The method of regulating the pay of these offices has doubtless much to do with the practice. Where the surveyor receives no salary, but is allowed to collect certain fees for work performed, there is some color to the claim that his work is private work and belongs to him. That this is not true concerning the public work done by these surveyors and engineers is believed to be evident from what has proceeded."

The editorial article goes on with laying down a set of rules to which each property map should conform, and further suggests the enactment of laws to force compliance, but I prefer here to finish this paper.

I have observed with pleasure that gradually many landowners in the suburbs of this city are placing permanent monuments at important corners, and if this practice is extended the value of private field notes will surely lessen.

If I am correctly informed, the practice of considering notes of surveys, relative to other people's land, as private property has grown out of the undeveloped conditions of this country in years gone by, when the engineer's private office was the only depository of such records. I have no doubt that in the course of time the importance of public records will be more and more realized, and with their growth and development will come an end to "private field notes" as a factor in the engineering profession, in which they should have no place.

MECHANICAL DRAFT.

By Henry B. Prather.

[Read at the regular monthly meeting of the Engineers' Society of Western New York, Buffalo, N. Y., July 1, 1895.]

Probably no subject is of more importance to-day to the engineer and to the manufacturing and steam using world than that of the economical combustion of fuel in the furnace of the steam boiler. That even with the best arrangements of modern steam plants for the conversion of calorific into mechanical energy but a small efficiency is obtained is a well-established fact, and yet possibly more startling than some realize. Theoretically each horse power should require about 0.212 pounds of coal per hour, and yet the very best engines and steam plants require from 1½ to 2 pounds, —*i.e.,* about ten times as much and good practice fifteen times as much and the great majority of good engines in daily use fifteen to twenty times as much,—*i.e.,* 3¼ to 4¼ pounds coal per horse power per hour and show a ratio of actual performance to the full calorific power of fuel consumed of 5 to 8 per cent. A great portion of this loss of 9-10 to 19-20 of the work represented by the fuel combustion is unavoidable, arising as it does from the physical qualities of water employed as a vehicle for the use of heat. A perfect heat engine could save but about 16.9 per cent. The best designed engine and steam plant will in fact yield but about 6 to 8 per cent., and hence the ratio of practical performance to the perfect plant under usual conditions is about 35 per cent.; in other words two-thirds of the heat work that may be striven for is lost. This loss is in the engine chiefly, and also partly in the boiler, and hence appears the vital value of improvements in combustion and boiler efficiency which will tend to reduce this two-thirds loss of possibly available work.

This subject has commanded the best efforts of our greatest steam engineers for years—men such as Chas. E. Emery, John C. Hoadley, Wm. R. Roney and others have given the subject exhaustive study and experiment—with gratifying results, it is true, but that there is still a wide field for improvement will be realized when it is understood that the relative efficiency above referred to of 6 to 8 per cent. has, with such economy facilitating devices as mechanical draft, water grates, improved furnace and boiler designs, mechanical stokers, etc., been improved upon only to the extent of 10 to 30 per cent. There are, besides the high-class modern steam plants of comparatively recent installation, a vast number of plants, large and small, on land and water, where limitations of first cost

forbade improved devices, and even many high-class boiler plants which are susceptible of great improvement in efficiency, and offer a large field for apparatus tending to such and obtainable at a reasonable or low cost. Examples of such plants are the many small power plants in our hotels, office buildings and factories, and on board our many passenger and freight-carrying steamers and barges. There are many applications and devices on the market which claim to have the panacea for all the evils a boiler plant is heir to; some are really of value, some are purely "quack" devices. Hence a study of this subject is of great value from a negative as well as from a positive standpoint. It is hardly less worth while to know the absolute limitations of economy in coal combustion, to know what cannot be done, to know the good and bad features of exploited devices, though quacks promise never so much, as to learn by what means some of the important loss of heat in existing arrangements may be saved and put to use at a reasonable cost and without undue trouble. It is the object of this paper, by a description of some of the most important experiments and data made and obtained in the line of boiler economy promoting devices, and especially of mechanical draft and a brief discussion of the same, to possibly present some valuable matter and at least start discussion and thought on the subject in the Society. The limitations of a single paper of this kind and the time allowed the writer for preparation of same will not permit a full consideration of the subject, and especially detailed accounts of experimental data and the many arguments pro and con on the debatable points. The importance of good draft, natural or artificial, for the supplying of sufficient oxygen for the rapid and economical combustion of fuel has long been appreciated by intelligent engineers. The gain both in efficiency and capacity obtained by the rapid and energetic combustion of the various kinds of coal and the resulting high furnace temperature is well established. Its importance has, however, been generally conceded only within a few years. The wonderful stimulus which the development of electrical industries has given to the building of compound engines has necessitated higher boiler pressures, and this in turn has greatly increased the use of water tube boilers. High initial furnace temperature is essential to the best economy with all types of boilers, and especially with the water tube type, with their large amount of heat-absorbing surface in close contact with the products of combustion, as otherwise the temperature of the gases will be lowered below the point of ignition and will pass up the chimney only partially consumed. To obtain this high furnace temperature requires proper draft to deliver

an abundant supply of oxygen to the furnace. This result is obtained by two well-known means,—viz, natural draft produced by a column of heated gases in a chimney of suitable proportions, and "forced draft," obtained by mechanically creating an air pressure under the grates with a blower or fan. A third means, less known, is mechanical exhaust or induced draft, produced by a suction fan arranged to draw the waste gases from the furnace and discharge them into a small stack. These are the various systems of mechanical draft in general use. Special features for further increasing the efficiency of the apparatus, such as utilizing otherwise wasted heat in escaping furnace gases to heat the feed water or the feed or supply air, are often added. There are numerous other devices, such as hollow "wind grates," in which the grate bars are hollow and kept full of air under pressure, but constantly escaping to feed the furnaces through small holes in the grate bars, and others. The above-mentioned, however, cover the most successful arrangements. The principal advantages urged for these various mechanical draft systems over natural draft are, first, the more effectual combustion of fuel by reason of the more abundant and intimate supply of oxygen to the furnace, using any kind of fuel; second, the obviation of the necessity for high chimneys; third, the possibility of use of a cheaper grade of coal at the same time with a proper combustion of the same, and, fourth, the almost practical abolition of the smoke nuisance by reason of the more perfect combustion of the fuel and gases.

It has been urged that the use of the more rapid draft causes early deterioration of the grates in the case of the "cold air" forced or exhaust draft by the great difference in temperature between the air supplied to the under side of grate and the incandescent fuel on the upper side; in the case of the hot draft, either forced or exhaust, by the great temperatures obtained under and on the grates causing burning or melting down of the grates. It can be shown that the first-named evil is largely exaggerated, and can be rendered slight by taking the supply of air from the boiler room and from over the boilers; as to the second criticism, which has also been exaggerated, the use of water grates,—*i.e.*, hollow grates,—with a circulation of water in them overcomes the burning out of the grate bars, even with the maximum obtainable temperatures. There is no doubt but that many of the old-time "forced draft" applications where high speed blowers deliver cold air at 2 to 3 ounces pressure under the grates, and having no economizing device for utilizing the waste gases escaping up the chimney, are not as efficient as they should be; are great consumers of power for fan propulsion and

destructive of boiler grates and shells. True, they do "make steam" quick, and when coal is shoveled in fast enough they are great "steam raisers." Of such plants a large majority have been applied on ocean steamers where limited space forbids the use of large slow-running fans and low velocity air conduits, and the principal object is fast steam-making more than economy of fuel. The value, however, of the use of even cold forced draft at pressures of $\frac{1}{2}$ to $1\frac{1}{2}$ ounces, and still more of the forced or exhaust draft with hot draft and economizer attachments in effecting an economy of from 8 to 20 per cent., is well established, and from 8 to 36 per cent. is claimed. Slow speed fans should be used whenever possible, in order to reduce the power required for fan propulsion. In this connection a brief consideration of results obtained by eminent engineers will be pertinent. From the summer of 1881 to May, 1882, at the expense of a number of the largest mill owners in New England, extended tests of "Marland's warm blast" apparatus were made under direction of the late John C. Hoadley, M. E., of Boston, at the chemical works of the Pacific Mills, at Lawrence, Mass. This apparatus consisted briefly of a "Root" positive blower exhausting the furnace gases upon leaving the furnace through a number of thin tubes about 3 inches in diameter, over which tubes the air supply for the boiler furnace was led and warmed, and thus effecting the economies of increased air supply, more effectual and complete combustion and warm feed air and its attendant results. These experiments were on a very practicable and elaborate scale, every detail being attended to and in degree of accuracy of calorimetric, anemometric and thermometric work were doubtless the most extended and valuable tests ever made of the kind. The most vital point in boiler testing, the analysis of the flue gases, was very carefully determined and elaborated, and the greatest care was taken in determining the exact power used in driving the blower or fan. The results obtained showed beyond a doubt a net saving of 10 to 18 per cent. over the best obtainable practice with natural chimney draft, and with air supply at the usual external air temperatures, at least five times as much as can be saved by any and all other methods save analogous devices (see Transactions of American Society of Mechanical Engineers, Vol. VI, pages 676-842). This apparatus has been in use several years, and no unusual deterioration of boiler, boiler grates or the warm blast apparatus itself has occurred, thus effectively demonstrating its practical efficiency. The induced or exhaust draft with feed water heating economizer as applied in many large plants consists of large slow speed fans exhausting the furnace gases over coils of feed water

heating pipe and discharging the refuse gases up short stacks or chimneys and outdoors, thus utilizing the waste heat of the gases to heat the feed water for the boilers. Mr. Wm. R. Roney, M. E., of Boston, Mass., is probably the best authority on this form of mechanical draft. The results of his experiments in brief, as lately stated by him, are the first cost of a properly designed mechanical exhaust draft plant is very much less than that of a suitable chimney of equal capacity, usually averaging 75 to 80 per cent. less; and as to power required for fan propulsion in a plant with 6000 H. P. water tube boilers, the power required to drive one fan to do this work was 6-10 of 1 per cent. of the boiler horse power developed or estimated in coal per horse power per hour at $3.00 per ton; the fuel cost of running the plant one year was 2 per cent. of the estimated cost of a natural draft chimney for the plant. In other words, it would not pay to build a chimney so long as money was worth more than 2 per cent. per annum. In another case the power required was less than 10 H. P. for each 2000 H. P. produced, or less than half of 1 per cent. of the power developed by the boilers; and in a tabulation of the results obtained in nine large plants the average net fuel saving was about 15.2 per cent., and in some nearly 20 per cent.; and, in addition, there was the economy in first cost and in the money which would otherwise have been invested in chimneys.

Referring to those feed water heaters commonly known as fuel economizers, they are certainly no new thing, having been manufactured in England for over fifty years and in this country for three or four years, and have been imported for many years. They have been used, however, almost exclusively in chimneys with natural draft, and hence on account of the reducing effect on the draft caused by lowering the temperature of the gases and retarding their flow it is always necessary to provide a better draft where they are to be used than when not; hence, higher and larger chimneys. Good practice requires that chimneys with economizer should never be less than 200 feet in height. Certainly, the failure which has sometimes attended the introduction of the fuel economizer has often been due to placing them where the chimney draft was none too good before; hence, they not only failed to show an expected economy, but also impeded what draft there was. Of course these objections do not hold when mechanical draft is used; a short chimney can be used only high enough to permit the discharged gases to clear neighboring buildings, and the heating surface in the economizer can be made a maximum and the gases cooled to a point which would destroy the draft altogether in even the tallest

chimney using natural draft. In the designs of new plants and chimneys for same this point of small chimney required is extremely important in first cost, especially in this day of valuable land around our city power buildings. Mechanical draft possesses great advantages over natural draft, especially in its flexibility of application and adaptation to both large and small capacities and in its ability to meet sudden and excessive demands for steam either by an extra turn of the throttle valve or by use of an automatic regulator controlling the steam supply to the fan engine, and hence adjusting the speed of the fan according to the boiler pressure. No such flexibility of adjustability can be had with natural draft. It should be noted that in no system of exhaust draft so far referred to in this paper does the suction fan handle the furnace gases at their furnace temperatures; they pass through the fan after the major portion of their heat is absorbed by the economizer or by the "abstractor," or air supply heating device, the average temperature of the gases actually handled by the fan, even with the exhaust draft, being about 300 degrees, a temperature in no way deleterious to a fan of proper construction with "a water cap" bearing. The Howden "hot draft" apparatus has been applied quite successfully on the lake and ocean boats; this consists of a blower fan forcing cold air at about 1½ ounces pressure over tubes (through which are passing the hot gases from the boiler furnaces), and thus absorbing most of the heat from the furnace gases, thence discharging this hot feed air at about ⅓ to ½ ounce over and under the grates. Tests of these plants on the lake steamers "Madagascar," "Nicaragua," "Harvey H. Brown" and others have, on a comparison of comparative fuel consumption per ton cargo carried per mile, showed a gain in efficiency of 28 per cent. over work done without the hot draft and using a poor grade of bituminous coal; and showed an average combustion of 1.65 pounds fuel to each indicated horse power developed per hour, a most remarkable showing for the mechanical hot draft, as well as for the complete steam plants. The Ellis and Eave's system, as applied to the power plant for the American Line of steamers in New York city is on the same principle as the Roney exhaust draft plants, excepting that, instead of the feed water heating economizer, a feed air heater is used and hot air supplied to boiler; and for this system a gain of 20 to 25 per cent. is claimed, and certainly 15 to 20 per cent. can be relied upon.

Before closing this review of the most important systems before the public to-day the "Keene Fuel Economizer and Smoke Consumer," a form of mechanical draft, demands attention. This device consists of a fan blower taking in ordinary air on one side

and connected by means of a suitable pipe with a chimney flue near the breeching of the boiler on the other side, so as to take in more or less of the flue gases to heat the air, and delivering the mixture of air and gases to the ash pit of the furnace, whence they are forced through the grates and the fuel bed. Dampers are placed on each side to regulate the proportion of air and flue gases admitted to the blower. Tests of this apparatus under direction of the smoke commission of the city of St. Louis, Mo., showed an average temperature of the air discharged under the grates of 235° and a gain in efficiency over the same boilers without the device of 38 per cent.; and when using the fan, but not heating the air supply, a gain in efficiency of 26 per cent. and a smoke record of reduction of smoke emitted from stack of 90 per cent. is claimed. It will be noted from the above matter that the simple "forced draft" application of mechanical draft, consisting of a blower discharging ordinary air under the grates of the boiler, has not, so far, been largely touched upon. But there are twenty of these applications, however, to one of the more elaborate economizer or hot draft arrangements, and the proportion is probably much larger. There is no doubt whatever but that the addition of the special features referred to for further increasing the economy of the mechanical draft plant do so enhance their value, but there are, as before stated in this paper, a vast number of boiler plants already installed, and mostly of small size, whose efficiency is susceptible of increase and oftentimes badly in need of such an increase by the addition of the simple forced draft, and where the cost renders the same the only available apparatus. Great corporations, with their hundreds of thousands involved, can afford the most complete equipment and profit by the same, but the smaller steam users must often, and very often, purchase the lowest in price that they can get, and still improve their poor draft or abate their smoke nuisance, or both. A description of a few representative plants of this kind will be of interest. The elements are about the same in all cases, excepting in very small outfits of 30 horse power or under.

A steel plate fan with direct connected, single or double engine, usually vertical, exhausting the air from the hottest part of the boiler and engine room (thus serving to help cool the room, as well as assisting the boilers), discharges this air under the grates in case of stationary land boilers, or into wind boxes in front of ash doors for marine boilers, with suitable dampers and levers readily accessible for operation of same. An automatic steam regulating valve on the steam supply pipe to the engine for the automatic regulation of the engine speed in proportion to the pres-

sure desired to be carried on the boilers is generally provided. The velocity of the air at the fan outlet is carried at from $\frac{3}{4}$ to $1\frac{1}{2}$ ounces pressure, and under grates from $\frac{1}{3}$ to $\frac{3}{4}$ ounce; and a delivery for tubular boilers of about 150 cubic feet of air per square foot of grate surface per minute, and for water tube boilers from 200 to 300 cubic feet per square foot grate per minute is effected. A plant like this, with a 70-inch (narrow fan) and five by seven single engine was placed in the power and light room of the large dry goods store of Barnes, Hengerer & Co., of this city, about two years ago by the Buffalo Forge Company; has run successfully ever since with no unusual repairs, and has shown a net saving of at least 30 per cent. in the fuel bills and a relative gain in efficiency of 10 to 15 per cent., with a practical abolition of the smoke nuisance. The remarkable economy in the fuel bills arises in this case from the fact that before the introduction of this system the best pea coal and anthracite was burned, while with the use of the forced draft apparatus a soft coal slack is used, with tne addition of one barrel of good hard coal to about six or eight of the slack or cheap coal. Plants have been installed in the Genesee and Broezel Hotels, about twenty factories and manufacturing establishments and on the lake steamers "Wm. H. Gratwick," "Caledonia," "Italia," "Bulgaria," "Australasia" and others, with practically the same results, by the same firm. The illustrations herewith show the method of application.

As a conclusion it is pertinent to emphasize the fact that the most perfect mechanical draft plant will be a failure nine times out of ten if the firing of the boilers is not properly attended to, and the too rapid rushing of the air through the grates or the improper impeding of the draft by the kind of firing and the manner of stratifying the coal on the grates is not prevented. Engineers may design, and inventors may scheme, but the king of the boiler room is the fireman. Mechanical draft is a help to the fireman as well as to the man who pays the coal bills, if he would but appreciate it. The day of the tall chimney, belching forth its clouds of black smoke, which many a time has been cited as glorious evidence of prosperity, is about over, and the day of the development of one indicated horse power by one pound of coal, with all its enormous economies to the steam-using world, approaches, and no single agency in this good work deserves more praise or has been more useful than mechanical draft.

DISCUSSION.

Mr. Rodgers.—The speaker struck the keynote when he said the success of any method depended upon the fireman. I, how-

ever, take exception, and desire an opportunity to discuss it at another time.

Mr. Holloway.—What is wanted is perfect combustion, no matter how it is obtained. Even the best appliances are dependent upon careful handling.

ADDENDA.

Howden Hot Draft.

Report of chief engineer of Goodrich Transportation Company, of Chicago, showing results of fitting three of their steamers with this form of mechanical draft. During season of 1893 the steamers used Pittsburg coal without the Howden draft, and during season of 1894 they used Indiana coal (which could not be burned before) and with the Howden draft:

Str. Indiana. Season,	Miles run.	Tons of coal used.	Cost.	Pounds of coal per mile.	Saving.	Cost per mile run.	Saving.
1893	24,870	2,795	$9,191.90	224.7		.37	
1894	24,500	2,633	5,641.57	214.9	5 pr. ct.	.23	38 pr. ct.
Str. Racine. Season,							
1893	23,660	2,350	8,759.71	198.7		.38	
1894	22,770	2,000	3,987.50	175.7	12 pr. ct.	.18	50 pr. ct.
Str. Atlanta. Season,							
1893	23,615	2,791	8,903.40	238.		.38	
1894	22 680	2,320	4,838.44	205.	15 pr. ct.	.22	40 pr. ct.

Mechanical Exhaust Draft with Feed Water Heating Economizer.

Report of Wm. R. Roney, M. E., of Boston, Mass., on test made.

The per cent. saving is only a comparison, using same kind of coal. Undoubtedly a comparison of fuel cost between necessary kind of fuel to use without and possible kind to use with the exhaust draft would show a saving of 30 to 50 per cent.

Test of economizer and mechanical draft plants, showing initial and final temperature of flue gases and feed water in degrees Fahrenheit.

Plants tested.	Gases entering economizer.	Gases leaving economizer.	Water entering economizer.	Water leaving economizer.	Gain in temp. of water.	Fuel saving per cent.
1	610	340	110	287	167	16.7
2	505	212	84	276	192	19.2
3	550	205	185	305	120	12.0
4	522	320	155	300	145	14.5
5	505	320	190	300	110	11.0
6	465	250	180	295	115	11.5
7	490	290	175	280	105	10.5
8	495	190	155	320	1[illegible]5	16.5
9	541	255	130	311	181	18.1

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. AUGUST, 1899. NO. 2.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

FOREST MANAGEMENT IN MAINE.

BY AUSTIN CARY, A. M., FORESTER TO THE BERLIN MILLS CO.

[Read before the Boston Society of Civil Engineers, May 10, 1899.*]

IN any broad view of the forest interests of Maine we should begin with topography. The ruling topographical feature of the State is a broad plateau† stretching from west to east, dividing its area into a northern and a southern slope. Of these slopes the northern is the smaller, embracing the watershed of the St. John River. The southern slope is a belt along our entire coast line on the average 140 miles wide.

A further feature to be noticed is the fall of the divide from west to east, from the foot of the White Mountains, in New Hampshire, to Mars Hill, on the borders of New Brunswick. The Rangeley Lake system at the west is between 1400 and 1500 feet above sea. Moosehead Lake, at about the center of the line, lies at 1020 feet. The highest point on the boundary between Maine and New Brunswick is about 500 feet above sea level.

The botanical features of the State hang largely on the topography. In the southwest, for instance, a large district, low-lying and with a mellow soil, is united botanically with Massachusetts and Southern New Hampshire. Oaks are prominent in the woods here, and white pine was the staple of the original soft wood timber. On the other hand, the plateau country presents a Canadian flora. The hard wood trees are the birches, maples, etc., characteristic of

*Manuscript received July 11, 1899.—Secretary, Ass'n of Eng. Socs.

†For the original statement of these relations, and valuable information as to Maine's natural features and resources, see Wells' "Water Power of Maine."

a colder region, and spruce forms the largest and most valuable part of its soft wood timber. In the west, where the boundary of the plateau is sharp, and where it has its greatest elevation, the contrasts in timber stand are greatest. Eastward, with the easier topography, there is more variety and mixture.

We must next observe that a large part of the State of Maine is destined to remain permanently wooded. The bulk of our population is now and will continue to be located in the lower southern part, where milder climate, abundant water power and areas of fertile soil offer advantages. Again, there is a strip of land with easy topography and very fertile soil along the New Brunswick line in Aroostook County. Out of these areas indeed a large proportion is wooded, and some bodies of land included within them are of such a character that they never will be inhabited or cultivated. For the great district remaining, about half the area of the State, the same thing is true. It is high in the first place, and the season of growth is short. As a rule the topography is rough and the soil poor. Considerable of it, indeed, is little more than ledges and piled up rocks.

Half the area of the State, then, about 15,000 square miles, seems destined to be permanently forest. This is an area twelve times as large as the Black Forest* in Germany. The States of Massachusetts, Rhode Island and Connecticut, taken together, just about equal it in area. The importance of this body of land as a source of wood material is evident from the statement. The relation to it of business development will be seen later on.

Since its settlement Maine has always had a lumber business; that is to say, lumber has been cut and sawed here not only for local consumption, but to export to other communities. Many of the earliest settlements in the State were built about accessible mill privileges, and later movements of population have in considerable measure been related to woods and mills.

The development of the lumber business has proceeded according to evident laws. In the natural condition pine was at once the largest, most valuable and most accessible timber that the State possessed; pine, therefore, was the first timber to be taken. It was taken, too, where most easily accessible, along the coast and on the banks of the rivers, where it could be floated to mills, run by tide or located at the first powers above their mouths. As the best class of timber failed in the first locations men pursued it further up the streams, or spread along the coast to other regions which had not yet been drawn upon. For a long period, however, they cut

*The amount of actual forest land is here meant, not the gross area.

only pine, even after they had to go long distances for it. In fact, the State had been settled nearly two hundred years, and the larger rivers had been culled for pine clear to their sources on the plateau, before there was a profitable market for other soft wood timber. At length, however, the limits of the pine supply, a supply never so abundant per unit of area in the northern wilds as in the low-lying parts of the State, began to be approached, and spruce began to take the place of pine as the staple of lumber export.

Since about 1840, then, the bulk of the lumber exported from Maine has been spruce, which was cut in the great forests of the plateau and sawed at mills located low down on the Penobscot, Kennebec and Androscoggin Rivers. Since the early 70's, however, the saw mills have had a competitor in the log markets of the State in the shape of mills manufacturing wood paper. Beginning about 1870 in a small way, pulp and paper manufacture rapidly increased, and in ten years had become well established. After a period of experimentation spruce wood was settled upon as by far the best technically for most uses, and it is now exclusively used in most mills. The amount of this use can be judged of from the mill capacity. In 1894 the pulp and paper mills of Maine numbered forty, and represented, as reported to the State Labor Commissioner, an invested capital of $12,000,000. They employed between 4000 and 5000 men, and had a daily capacity of 397 tons of paper and 765 tons of pulp. At the beginning of 1899 the mills of Maine reported to the directory of the trade a daily capacity (not production) of 650 tons of paper and more than 1000 tons of pulp. In this respect Maine stands second only to New York among the States of the Union.

Here we get at what is at once the big and the pressing matter in connection with the forests of Maine. Paper making is one of the great, stable and growing industries of the country. It is mainly dependent on spruce wood because spruce excels in length and strength of fiber, and is most readily reduced to the macerated condition. Now the woods of Maine possess the largest stock of spruce wood existing within the limits of the United States, while probably in a still greater degree they embody growing capacity. The question what that resource amounts to, the question, too, how it is being used and what may be done to foster it, are questions of concern to the whole country.

The people of Maine have been behind in the appreciation of their natural resources. The State is approximately 31,500 square miles in area. Wells in 1869 estimated, excluding water and cultivated land, that two-thirds of it, or 21,000 square miles, was covered

with woods, and the conditions since then have not greatly changed. The area destined to be permanent forest, as earlier defined, we may set at about half the area of the State, or 15,000 square miles. Probably more than that, even taking out waste areas in the shape of burnt land and barrens, now possesses spruce of at least some small value. As to amounts of timber standing, no careful summaries have ever been made, except for some comparatively small portions. Much of the country never has had the timber upon it estimated, and if that had been done a vast amount of digestion and re-exploration would be required before the figures could be safely compared and summarized. The best that can be done here to give an idea of the condition of the Maine woods is to describe very generally and cursorily different tracts of country.

Some 12,000 square miles on the St. John and upper Penobscot are timber land of very varying quality, containing every variety of stand natural to the region. Considerable areas in the aggregate have never been cut for spruce, and the cutting that has been done has generally been for saw logs of good quality merely, and pretty loose and unsystematic. The area named has not been seriously damaged by fire. Here, due to its area rather than quality, is the great supply of spruce wood now existing in the State.

The Kennebec River drains 5800 square miles, but less than half this area could be classed now as actually spruce producing. But at the heads of the streams, in very difficult situations, small tracts yet remain that never have been cut for spruce; but the remainder has been cut through, much of it severely and several times over, while both in early and more recent years the region has suffered severely from fire.

The Androscoggin River possesses about the Rangeley Lakes the best spruce timber land in the State. It has been saved from fires, and, due to the roughness of the land, much of it has thus far escaped cutting. The drainage is of small area, however, 2750 square miles in Maine, and half of that, in the lowlands of Southwestern Maine, cannot be considered as spruce producing. There is also a great mill capacity located in this region. At Berlin, Livermore and Rumford are some of the largest paper mills in the world, and while they draw in a considerable portion of their wood supply from Canada and elsewhere by rail, the Androscoggin drainage itself is being called upon for timber at a rate and in a manner that will within a few decades, if continued, blot it out as a source of spruce timber.

Other items of the timber supply of Maine are of minor importance, at least in the present connection. Southwestern Maine has

white pine as its main soft wood growth. This is a quick-growing wood, and on it that part of Maine does a considerable lumber business. This item is seldom thought of in connection with the lumber supply of the State, but, as a matter of fact, wooded lands in this region are probably producing more per acre than the backwoods. Pine, however, is seldom used in the manufacture of paper.

Most of Washington and Hancock Counties, in the southeast, consist of poor and rocky land, fit for nothing else but the growth of timber. This country, however, has been long and hard cut. A good half of its area, too, has been burned over, and while burned land almost always quickly grows up again, fire changes the character of the growth and sets it back as a producer of lumber. As to spruce supply, as available now and in the next fifty years, the main items have been considered already.

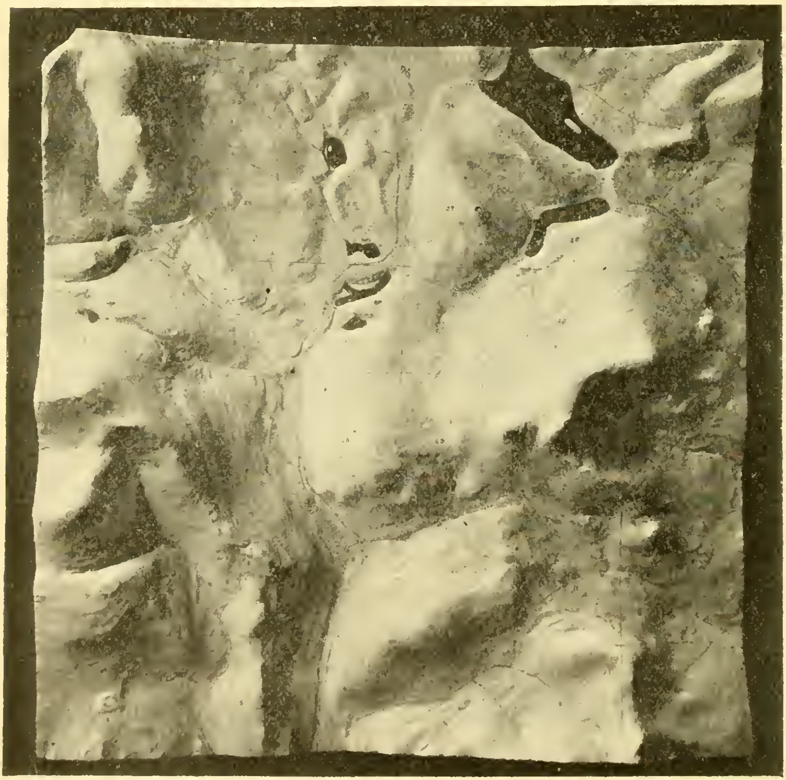
Under the circumstances it is perhaps rash to set any figures for the timber resources of Maine. In stating clearly, however, that such a figure can be merely a rough guess consequences of presumption are deprecated. It seems probable, then, that twenty-five billion feet, board measure, may approximate the amount of spruce wood standing in the State. The total lumber cut in the State in 1896 was something over six hundred millions. Of this probably five hundred millions was spruce. About two-fifths of this went to the paper and pulp mills.

Six hundred millions is equivalent to 30 feet per acre on the gross area of the State. Five hundred millions may be 50 feet per acre on the area of what we might call spruce producing land. These figures are within the amounts which such studies as have been made attach to ordinary cut-over land as its yearly growth. Certainly, they are small in comparison with what we know scientific forestry has produced elsewhere.

The general inference to be drawn from these facts is not a discouraging one. Our resources are still great, and we may feel justified in using them freely. It is to be remarked, however, that paper mill capacity in the State is being rapidly increased at the present time, and promises to reach in the near future a much greater development.

It might be remarked of the foregoing that it is business and not forestry. The reply to that is that whatever forestry we are to get in Maine, at least in the near future, must be worked out under business conditions. The State of Maine is not likely to interfere by law with the conduct of private business. Neither does it appear that State ownership of wild lands to any great extent is

likely to be brought about. Maine is poor in comparison with the States that have inaugurated that policy, while it is not called to that course by such urgency. Agriculture has not, to our knowledge, been affected by the cutting of our forests. The flow of our rivers has not been affected to such an extent as to elicit protest or a call for investigation. The climate of Maine is such that almost all denuded or burned areas very quickly reclothe themselves with growth which, if not valuable at once for timber, at least protects the surface of the ground beneath it.



Topographical model of township No. 3 R. 5, Franklin Co., Maine, showing, in addition to the waters and relief, bogs, roads, trails, section lines, etc.

The man therefore who would throw in his lot with the forests, who would economize in their use and maintain their growing power, must bring himself to bear on the forces in the field. He should not be choice in his weapons. The spread of information will accomplish much, but competition, when it can be brought to bear, may prove a more effective tool. Forestry should seek to

ally itself with business, to promote the success of careful and foresighted concerns. The forester, if he would work directly on the problem of management, must work in private employ and in accordance with its fundamental conditions. First among these is the necessity of making profit. Should the forestry practiced lead to loss, the business goes down and the forester's position and opportunity go with it.

The lay of the land in this quarter will become more evident if we briefly review the systems of landholding and management existing within the State. First is the stumpage-selling system, long current and now in vogue in the timber lands of central and northern Maine. The land title in this case is held by men who neither own mills nor cut logs. Neither, as a rule, are they practical woodsmen. They are simply men of means who have acquired lands by inheritance, or who, having found out that timber land is a safe and profitable investment, have bought it on the judgment of others. They sell lumber standing at so much a thousand, and do not as a rule exercise, either directly or through their representatives, any effective supervision as to how it is cut. The man who buys the stumpage may or may not own mills. At any rate, he is interested in getting as good a lot of logs as possible for the stumpage paid and with the least outlay of time and money. He cuts accessible bunches therefore, and leaves distant or scattering timber. He cuts his stumps as high as is convenient, and throws away a quarter of his lumber in the shape of the knotty tops, which, though capable of use, are of distinctly less value. He slashes through the country anywhere with his roads, and makes no attempt to spare young growth or to save such as is killed if it comes below the class of most desirable timber. In examining these matters a few years ago for the United States Forestry Division I found concerns where only 60 per cent. of the whole volume of trunk wood was saved from the largest and finest trees, and where, taking into consideration the small trees killed and left, the lumbermen put into the water less than half of the timber killed.

Such methods as these are an heirloom from former times, but they are rendered possible in the present only by the system of landholding under consideration. The trouble is the interests of the man who does the work are divorced from those of the land on which he is operating, and that this is not offset by strict contract and supervision. The power of remedy lies with the landowners, who are strong parties and who would benefit by careful handling of their lands. In a few cases this has been done. Thus the only really conservative force on the Androscoggin to-day is a large

body of land held in this way which is operated carefully and with a view to the future. As a rule, however, nothing can be expected from present owners. The only remedy is to buy them out.

Again, landownership in the past has often been a subsidiary part of the sawmill business. Men engaged in lumber manufacture found they could buy land cheaper than logs, and did so, going on often to do their own lumbering. In their cases logging work is frequently somewhat more economical, but it can hardly be said to be more foresighted. The man's object here is to stock his mill. Beyond that the land has no value.

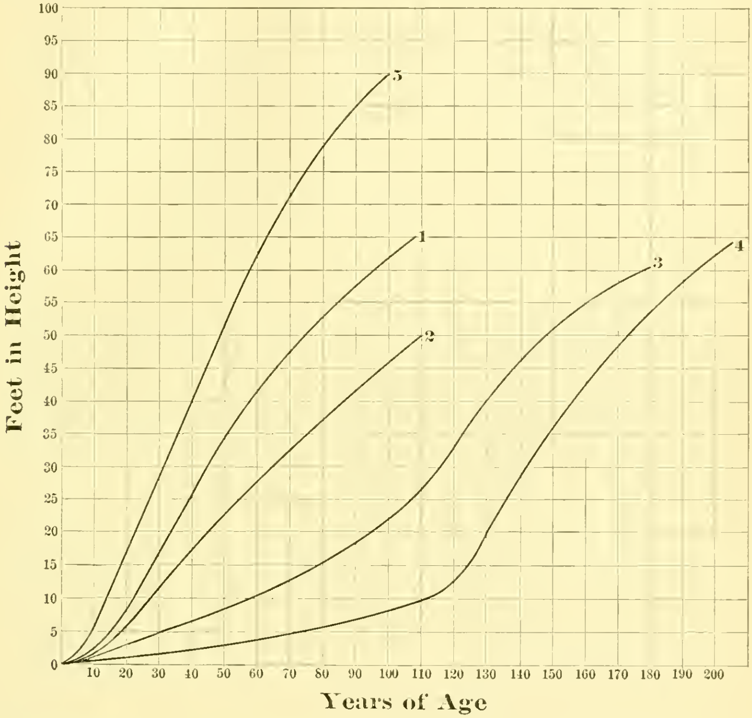
An example here, an extreme one, to be sure, will serve to show what is sometimes lost under the present methods of conduct of the lumber business. I happen to know where a very large amount of spruce timber, belonging to one concern and standing in one compact body, was killed by the ravages of insects. Within two years from the death of the trees there must have been a loss on the lumber not far from 50 per cent. After five years or so there would be nothing there worth going after. And yet, due to stupidity, obstinacy or to financial pressure, no adequate measures were taken to save it. In fact, the dead timber was left to rot, while nicely growing land that had once been cut through was stripped off beside it because logs could be got there a little cheaper. What good forest management consists of in such a case is very evident. The fact illustrates the principle that good forestry is very often identical with sound business. Neither one is possible if there is too great financial pressure.

Whatever the economy of his work, from the point of view of forestry, there is one fundamental trouble with the sawmill man's attitude to his land. He regards it simply as a source of stock for his mill. He buys the land to strip it. He wants to get his money out quickly and put it into some other investment. So he takes principal as well as interest, the stock of wood needed for growth and reproduction, and not merely the mature crop. If, in years back, owing to slack methods and the condition of the market, a good deal of growing lumber has been left standing, that is entirely aside from his main purpose and intention. At present some of our most destructive and thoroughgoing cutting is being done by sawmill men.

Since the pulp and paper mills began to be a strong factor in the log market of the State a good deal of hue and cry has been raised, because they cut or caused to be cut much of the small growing lumber. Small logs could be used by them to quite as good advantage as large ones, while, since they were less desirable

to the sawmills, they could be had much cheaper. There have been, therefore, of late years two classes of logs on our larger rivers, saw logs and pulp, selling at considerably different figures.

The pulp mills have been justly criticised on this head, and yet there are considerations here that should weigh strongly in their favor. They have worked great economy in the use of our forest resources, have taken vastly more from our lands than would have



Height curves, showing comparative growth of spruce and pine and of spruce under different conditions.

1. Curve of spruce grown on good soil,—land cleared by fire.
2. Curve of spruce on very poor soil,—same tract of burnt land.
3 and 4. Curves of spruces grown up in mixed hard and soft wood under shade.
5. Curve of a pine on same site as No. 1.

been possible under the old *régime*. The pulp mill can use the knotty tops; a seamy or crooked tree is as good as a perfect one; the small trees cut or smashed down, which in other times were left to rot, can all be utilized by the pulp mill. Sometimes tracts of land are given a value, and can be operated at a profit for pulp, which would never have been cut for saw timber.

And if, in the direction of economy, the paper mill has vastly raised the standard, it has seemed to promise the same in the direc-

tion of foresight. In beating about among the lumber consumers of the State, as just mentioned, the fact forced itself upon my notice that the men who were thinking pointedly about the matter of timber supply, the men who were most interested in anything that promised to increase and extend the yield from our forests, were the owners of pulp and paper mills. And, on consideration, the reason for this is plain. It is their great investment in mill plant, an investment dependent on forest supplies for life and profit. The contrast with the sawmill business is striking, and, in the present connection, vital. A plant that will convert seven millions of spruce wood a year through the stages of ground wood and chemical fiber into finished paper requires a capital, mostly in the fixed form, of not far from a million dollars. Many of our operating sawmills, on the other hand, represent a valuation of only $10,000 to $20,000. The paper mill man is tied; he is in the business for a long period. The sawmill, when lumber gets scarce or business poor, may be abandoned.

Thus we have had a movement among the paper mills, yet in its infancy, but apparently increasing, to back themselves with land enough to render them independent. With that movement has gone the purpose to treat those lands carefully and with foresight.

In this movement it seemed as if the financial basis might have been attained for conservative forest management, as if we had solved the problem of so disposing of the ownership of our forests that their value might be preserved and the community at large derive most benefit from them. Still more was that hope nourished last year when, at the organization of the International Paper Company, with control of 80 per cent. of the output of news paper of the country, a professional forester was employed, and the intention expressed of living, so far as forest supplies were concerned, within the limits of actual growth. It looked as if the paper mill, backed by forest land, the two operated together as one great permanent investment, was the form in which the bulk of our Maine woods might in time be held. This appeared the more likely because, as many of the mills have been situated, land sufficient to so stock and fortify them could be had for a less investment than the cost of the mills, so that heavy profit from the land part would be a minor matter in comparison with the safety and prosperity of the whole.

We may hope for much from this idea, and yet must be cautious in banking too heavily upon it. It seems sometimes as if American business enterprise were too grasping, reckless and shortsighted to have safely intrusted to it a great natural resource. Heedless desire for immediate gain tends to the overstocking of every profit-

able line, and ruinous prices and cutthroat competition follow in its wake. Thus men reckoning at the very closest on the price of paper are compelled to figure on the price of pulp wood as one element, and if that is done too closely it shuts out the opportunity to do anything for the land. On the other hand, the danger in combination is that business will be conducted with reference to the stock market rather than to sound business success. Either excessive competition or wrongly used combination is destructive of sound, liberal business. Either, in this case, will prevent doing anything to the advantage of the land.

At any rate, as a safe and satisfactory arrangement for the holding and operation of forest land, we have suggested to us the organization of companies of general investors. Forests, carefully handled, form a very secure form of investment, able to pay a moderate return without loss of capital. In Europe forests have proved the safest and surest investment, being used in that way not only by the noble families and others of the best class of investors, but being held for revenue by cities, towns and states. On the other hand, conditions are right here to keep the forest constantly producing. The investor looks only for interest, and wants his capital kept intact. By that means sufficient wood stock for growth and reproduction is left on the land.

There is vastly more in the woods business and in lumbering than might be imagined by the uninitiated. In developing a township of land for the first time the first thing to do is to get a road to it. Along that road, as business is now carried on in the most progressive localities, is strung a telephone wire. Supplies and communication are thus assured.

Next comes usually improvement of the streams. Our smaller streams are generally rough and crooked. Rocks have to be blasted out of the channel, abutments built to run the logs round sharp turns and keep them out of the swamps. Dams are constructed to control and prolong the flow of water. These improvements are costly. Some of them have a short life. They sometimes compel a concern to log heavily on a tract while they are there.

This is but a small part of the expenditure, however. On large lakes logs are towed more cheaply by steamer than by hand. Three steamboats of different sizes and patterns are employed to get past the lakes of the Rangeley system, and booms, dams and piers are needed at various points below. Again, several hundred horses are used in the woods work of the company by which I am employed, so that even in the small matter of harness no small

amount of care is required to keep a supply in stock, to keep run of it in movement and to keep it in repair.

An Androscoggin logging camp contains as a rule forty or fifty men. A woodworker and blacksmith are in every crew to supply it with tools and sleds. Two men manage the cooking, and often another has special charge of the stable and horses. The rest of the crew are divided up by the boss into squads; a teamster with a pair of horses and sled as the nucleus of each, and with him, to do the cutting, a crew of usually four men.

This crew, under present arrangements, works largely by itself. The boss of the whole crew gives it ground to work on, and spots out its main road. He tells the men in general terms what to cut, and visits them once a day to see that they are doing as they were told. Further than that, however, the men run their own work. A man of experience leads off, spotting his road and having a man to help him fell the trees. These two men also cut the log off at the top, cut the limbs off and roll or swing it to where it can be hitched onto by the team. The third man has to trim the knots close, bark the log if necessary, so that it shall drag easy, and, when the teamster comes along, help bind the load onto the sled. The fourth man, meanwhile, is ahead of all his mates, making a road by cutting out the trees and windfalls, filling up the holes, bridging brooks, etc. In our woods the men are mainly French Canadians and immigrants from the British provinces, with some Yankees and a sprinkling of men from the northern countries of Europe. They vary much in experience and capacity. Good men, over and above board, are paid from $20 to $26 a month.

These are the men that the forester has to work with. This is the organization he will have either to utilize or modify in carrying out the purposes he entertains toward the forest. So far this organization has been trained simply to rapid, clean cutting. It has had to get its lumber and get it cheaply, and that is all there is to it.

The forester, in cutting through our spruce woods, wants to leave a stock for reproduction and growth. This, of course, can best be left in the shape of young trees. No one is more interested than the forester in removing, and so saving, all dead timber that can still be used, and also any defective and declining trees. Usually financial considerations will require much more to be taken, probably two-thirds of all the merchantable timber. If so, the forester is as interested as anybody in having that done thoroughly and well. It must be done economically, however, without waste of wood, and it must be done with as little damage as possible to the

young growth which it is desired to retain. And right here, in the matter of saving and protecting the young trees to form a future stock, is where the forester meets his difficulty, both with the men he has in charge and with those who in turn are over him. The way ordinary lumbermen rip, smash and destroy young trees makes a forester sick to the stomach. And, on the other hand, the requirements imposed by his employers in respect to the amount of timber that shall be taken, the form in which it shall be got out and the expense of the operation make it often very difficult to do anything effective for the land. Not the least of the obstacles encountered is the logging boss. As a rule he is very efficient, but having up to the present been a despot in his own domain he is often as opinionated and self-willed an individual as can be met with.

Nothing will convey so clear an idea of the problem involved as comparison and a brief record of experience. In the Adirondacks, under the lead of Messrs. Pinchot and Graves, now of the United States Foresty Division, large tracts of spruce land have been taken in hand, carefully surveyed and examined, and cutting work has been begun in accordance with a carefully studied plan. The ground to be cut through there is traversed the summer before by the forester, and every tree that is to be cut is marked. The cutting itself is very strictly supervised, and no departure from the work marked out is allowed except for the strongest reason. Lumbering methods in the Adirondacks differ somewhat from those of Maine. There is less road cutting. Timber is cut into 13-foot logs where it is felled, and dragged from the stump onto yards by one horse. Now Pinchot and Graves state, in their volume, "The Adirondack Spruce," that in this way they can take out of the forest just such trees as they want, and do practically no damage to the remaining growth. A statement of what they found to be the average stand at Dr. Webb's Ne Ha Sa Ne park will make the matter clear. For spruce alone they found 158 trees per acre under 2 inches in diameter, 75 trees 2 to 6 inches diameter, 37 between 6 and 10 inches and 31 trees 10 inches and over in diameter that would scale about 3700 feet. In reference to these they state that the 31 trees per acre over 10 inches in breast diameter can be cut out and yet leave practically all the 37 6 to 10-inch trees and the 233 of still smaller sizes to form, as they would, a good growing stock on the land.

In my experience of one year under conditions outlined above no such results were attained as that. First, as accounting for that, was the character of the timber stand. Here, for instance, is the average stand of about 15 acres calipered over on one par-

ticular tract. Spruce over 4 feet high and under 6 inches in diameter numbered here 64 per acre. Trees from 10 inches in breast diameter, inclusive, down to 6 inches number 29, and would scale, if cut, about 800 feet. Trees 11 inches and up in breast diameter numbered 47 per acre, and would scale somewhere about 8000 feet. We have here a larger amount of merchantable timber per acre than in the Adirondacks. It is, however, due to size rather than to the number of merchantable trees, while the number of small trees ready to form the succeeding stand is far less than there. To the landowner in consequence the grown timber is of more concern proportionately than the small, and the forester's task of keeping the land stocked is, outside of the natural disadvantages, rendered more difficult.

Again, the forester's work was impeded by the business conditions. The lumber cut on the tract I speak of was to be used, all the largest and best of it, in the sawmill. It was essential, therefore, in order that it might saw to advantage in filling orders for timber, that it be cut long. The logs were, in fact, cut as long as could be driven out of the stream, 35-40 feet. When a tree would make more than that it was sawed into two logs. Now the heavy logs on rough ground required two horses, particularly as they were not being bunched up into small yards for a wagon sled haul, but being dragged often a mile or more directly to the river. Now a road has to be cut out wide for two horses loaded with long logs to get through, and many young trees in consequence are sacrificed. Nor was that the only disadvantage. The weight of a big butt log was heavy for men to handle. It could not be moved far, but trees had to be laid in felling close to the road where the team could get at them, while stuff had to be laid crosswise to roll it on and keep it from bedding down in the snow. Thus in thick timber along a road practically everything would be cut or smashed, and about all that was left would be in the strips between. Much of this could not possibly be helped under the conditions and within reasonable limits of expense. It is often the case that the thinner stands are left with the more promise of growth upon them.

Still, something could be accomplished, and that appears on all accounts worth while. Setting a general size limit of 12 or 15 inches breast high, according to the stand, the crews would go through a country cutting out the dead stuff and the larger timber in a more or less bunchy fashion. On knolls and divides particularly exposed to winds they would be required either to cut everything or let everything stand. The ideal could not be accomplished anywhere. Some timber would be left above the size limit, some

that had no promise of growth in it. On the other hand, more than a third of the small stuff would be cut or smashed down. This, of course, would be hauled and used when large enough to be handled without loss, but it was material which we should have preferred to have grow. As a net result we would leave usually from 1500 to 3000 feet of growing timber on the land.

This is descriptive of a first attempt. In large measure it illustrates how not to do it. It is clear to me that if we are to do anything worth while in forestry our organization in Maine must be tightened up. This is necessary in order to accomplish the purpose of forestry, to leave the land in good shape to grow, but I believe it will pay on the score of simple economy of wood and labor. In particular, if we are to leave our forests in shape to do their best in the way of wood production, the choice of the trees that are to be cut must not be left to ignorant and shifting choppers, but the trees must be marked beforehand by some one who understands the methods and the purposes of the work. In my opinion the logging boss and not the forester is the one who in the conditions of our business here can best do that work.

In adherence to the main purpose of this address, I cannot omit a brief reference to another and in itself a more attractive branch of the forester's business, tree biology and the theoretical grounding of forestry work. Take the matter of tree growth, for instance, the measurement of producing capacity.

Each year's wood growth of a tree is deposited in a ring surrounding on all sides its previous volume. The boundary of each year's growth is usually well marked, and the thickness can consequently be measured. In practice it is better to measure the rings in groups, say of ten each, beginning at the bark. The numbers of rings, taken at several log-cuts along the length of a tree, give us, with the diameter of each section, the means of computing the tree's growth for the last decade or for any preceding period. That gives us the individual tree. Hundreds of such computations, made on trees of different thrift and size, allow us to average, and, taken in connection with surveys of number and size of trees the country over, enable us to estimate the growth in a valley or a township.

From the same observations inferences of great value are drawn as to height growth. If a tree, at the ground, has 200 rings we know that it is, at least approximately, 200 years old. If 20 feet above ground we find 150 rings we know that the young tree consumed 50 years in growing to that height. So on up through the number of sections.

The facts are best represented in graphical form. Thus a spruce growing on a piece of burned land at Moosehead Lake was cut down, leaving a stump a foot high. There were 98 rings in it. Fifteen feet above there were 77 rings in the section, showing that 21 years were consumed in growing that height. Ten and one-half feet higher there were 66 rings, and the same distance above 53. The tree, as cut, was 65 feet high, and, allowing ten years of height growth for the stump, it was grown in 108 years. These facts are represented in curve 1 on the diagram, which will need no further explanation.

The value of this method of representation will be best brought out by comparison. Curve No. 2, for instance, represents the height growth of a spruce which grew in the neighborhood of the other tree, and in the same conditions, except those of soil. It was standing, in fact, on a bed of rocks. No. 5 is the curve of a white pine which grew up with the first spruce, and was of the same age. It shows the rapid production of that species.

Curves 3 and 4 are still more interesting. They represent the growth of spruces which stood in mixture with hard wood in forest whose history had been unbroken for centuries, which had trees of every age and size. Young trees starting in such conditions have to bear shade; they grow slowly for many years, and only perhaps after a century of struggle do their tops get out into free sunlight. And the point is that our spruce can survive and retain its vitality through a long course of such treatment. The tree represented by curve No. 4, for instance, at 125 years of age was only 15 feet high, and contained probably less than one cubic foot of wood. Yet, even by that treatment, the vitality was not crushed out of it. Getting finally free from suppression, it began a height growth equal to that of young trees which never had been suppressed.

Now, study of our spruce timber shows that the bulk of it has come to us through some such history as this. Knowledge of this gives us an important rule for guidance in management. That is, that young spruce in our woods, no matter if they are thin-crowned and seedy looking, yet retain their vitality, and if in our cutting we will at the same time protect them and open them to the light they will reward us for it. This is one great advantage of our spruce. The species is remarkable in this respect.

Last in this line I will present some figures on the volume growth of spruce trees, illustrating what that is in percentage and actual amount. The trees taken for observation ranged from 7 to 14 inches in breast diameter. They were 340 in number, and observed results have been arranged and evened by drawing curves.

Inspection of the last column, the amount of yearly growth in wood, shows that growth steadily increases as the tree grows larger; that up to the largest size here represented there is no slack. From this point of view trees of this size are not ready to cut.

Growth of spruce on thrifty spruce land on the Kennebec River, Maine, in volume and per cent. From third report of the Maine Forest Commissioner:

GROWTH LAST TEN YEARS.

Breast diameter.	Volume of tree.	In diam., inches.	In per ct. at compound int.	Yearly growth in cu. ft.
7 in.	6 cu. ft.	1.1	4.3	.26
8 "	8 "	1.15	4.1	.33
9 "	10.5 "	1.2	3.7	.39
10 "	14 "	1.23	3.25	.45
11 "	17.5 "	1.23	2.9	.51
12 "	21.5 "	1.23	2.6	.56
13 "	26 "	1.22	2.4	.62
14 "	31 "	1.2	2.2	.68

The column next preceding shows the percentage that the year's growth bears to the volume of the tree in the different sizes. Here the course of the figures is the other way. According to the table, a quarter of a cubic foot on a tree 7 inches in breast diameter amounts to 4.3 per cent., while twice as much wood on a tree 11 inches through amounts to but 2.9 per cent. Here the forester is checked by financial considerations. The larger he lets his trees grow the smaller is the rate of interest earning on his capital.

Much might be brought out in this connection. I will draw only the practical inference that one prime object of the American forester, who will be required to gain as rapid returns as possible, must be to change over the stand as nature gives it to him, with its large trees and comparatively small rate of accretion, into a thick stand of smaller timber more quickly growing and reproducing. That is particularly applicable to spruce when it is to be used in paper manufacture.

For the present, however, all these matters will be secondary in the mind of the working forester. Conditions vary through the country, and everywhere investigation and instruction have their field. But the man who, in conditions similar to those of Maine, is bent directly on the task of bringing forestry actually to pass, will endeavor to secure first the right financial conditions for his work, and secondly to so organize woods work that it will carry out his purpose toward the land in lines both simple and plain.

I wish to present one more topic, a topic of an engineering nature. Men of your training do not have to be told that topography determines very largely the course of all woods work.

Neither do you require to have explained the usefulness of a topographical map. Every lumberman is a topographer in a sense. Clear knowledge of topography is essential to the man who, from a central point, directs the conduct of a large business. So far in the lumber business each man has learned his own topography by cruising, and has carried it in his head. The limitations of this system are evident. Such knowledge is inaccurate in the first place. Then it is likely to be forgotten, and it cannot be conveyed to another man. The loss is particularly evident when one manager drops out of a business and his successor has to acquire his knowledge of locality all over again.

In the autumn of 1896 I had the good fortune to be sent by the Hollingsworth & Whitney Co., of Waterville, Maine, to make what I suppose is the first genuine topographical survey ever made of a New England timber township. The results, in the shape of a contour map and a model, proved so much of a satisfaction to the company and its superintendent that other concerns were led to desire the same thing. Thus I have been employed to survey in all about 125,000 acres. I think, furthermore, that in the economy of the spruce forests of New England topographical mapping has come to stay. A brief description of the methods employed in this work, developed as they have been in the work itself, with the aid of such hints and helps as could be got from outside, may be of interest to members of the Society.

The basis of the height work is leveling. If possible, connection is made with points known from railroad levels or otherwise, giving thus elevation above sea; then a line of levels is run over roads, or whatever else may be the best route to run on, to the ponds and other suitable marks well distributed through the township to be surveyed. From the points so determined by level I work off with aneroids, returning for correction as often as may be to some accurately known point. Two aneroids are usually carried; a thermometer is read with them as often as necessary, and changes of pressure due to the weather are recorded meanwhile by a barograph run by an eight-day clock located at the main camp.

The low accuracy of aneroid measurement is well known, but when carefully used with the aid of the accessories noted above, the aneroid suffices entirely for the purpose. A timber land manager does not require to know, for instance, exactly how high a given mountain is. The approximate relation of things is what he wants. The areas of valleys, the positions of streams and divides, the shape and steepness of the land, the grade of future roads,—these are essential points. Then the passes and their neighborhood often

require especial looking over, because it is sometimes very desirable to haul timber from one drainage to another, if that can be done without too much uphill work. In getting at all these points a land level has frequent use, in addition to the aneroid, or, better still, an Abney clinometer.

In these surveys the land has ordinarily been blocked up ahead of me into mile squares. It is a great advantage if, when the lines were run, marks were left every quarter-mile. Then one can locate himself quite accurately on a line by pacing and without going very far. These marks serve also as the starting point in examining the interior of a lot. For instance, after having traversed the lines of a lot, noted the crossing of brooks and divides, taken the height of essential points and noted or sketched whatever topography could be seen, I might start from the middle of one side to run a line across the lot. In doing this I often use a staff compass with 3-inch needle and folding sights, but perhaps more frequently a common pocket compass with needle less than 2 inches long held in the hand. Indeed, direction can sometimes be held more closely with the latter instrument. For instance, a man climbing over the *débris* left by cutting or shoving his way, head down, through dense thickets of young fir loses direction in the course of a few rods. Now if he has a compass in hand he will stop and look at it. He will do so less often if he has to set a staff, level his instrument and wait for the needle to come to a stand.

Meanwhile distance is kept by counting steps. Six or seven years ago, when I first tried to keep run of distance in this way, in retracing old woods lines, I found I required about 2400 steps to the mile. Later on, either because with practice I became longer gaited or because, without knowing it or meaning to, I discounted more, the number required became less. I found at one time that I was using 2200, and finally I got down to 2000 to the mile. There I expect and desire to stay, because at that rate notes plot so readily. In field sketches and in final maps I have so far used a scale of 4 inches to the mile. On that scale, at 2000 steps to the mile, 100 steps are two-tenths of an inch, and a half-inch square, or a piece of ground 250 steps on a side constitutes 10 acres.*

By one who has practiced it, measurement by pacing can be made, even in rough land and bad walking, much more accurately than would be supposed. One travels along, looking at the country, keeping his count in some back corner of his mind. Every

*Much help has been received on this and other points from the methods of the U. S. Geol. Survey in Michigan and Wisconsin, as communicated by Prof. W. S. Bayley, of Waterville, Maine.

hundred passed is marked down or scored by breaking an elbow in a tough twig carried in the teeth or hand. When a brook is passed or a change in the land occurs note is taken, the barometer read and the count begins again. Steps taken to get round obstacles are not counted, and on strong slopes discount is made. On very steep ground, indeed, steps taken are not a guide to distance, and judgment has to be resorted to in order to fill in the count. As first remarked, however, long practice enables a man to reach greater accuracy than would be supposed. Thus I am seldom out over 100 steps from the 2000 in crossing a lot. The count tells me when a line is approached, and enables me to pick it up with certainty, though it may be blind. Then I go right or left till I hit a quarter-post, and so ascertain the variation from the true compass course. By this means locations are made with considerable accuracy along the whole line.

What has been said makes it evident that a pedometer in just this kind of work can have but little use. It answers very well in smooth going, but its readings are no guide to distance on rough land. In my work it has been used merely as a matter of interest to estimate the number of miles traveled in a day or on a whole job. It is, in fact, a good deal of satisfaction after cruising a rough township, perhaps half-covered with brush heaps and blow-downs, to figure up and tell the company just how far I have been.

On simple ground running once across a lot serves, with a traverse of its boundaries, to give topography sufficient for the purpose. Elsewhere there are roads and streams to locate and divides that should be carefully put in. Here compass and pacing are still used, tying in to the lines as often as may be. Travel in parallel straight lines, however, has advantages if it is sufficient for the immediate purpose in hand. It is more accurate, in the first place. Secondly, if, as will no doubt be usual, the timber land topographer also understands timber, and is expected to report on its character and amount, systematic travel of this kind insures his seeing a fair sample of all the land. Timber estimates in the past have been notoriously inaccurate and misleading in their results, and one great cause of this has been that the men who made them did not see all the land. Of the accessible parts, perhaps of the good parts, they saw too much. They did not fairly balance the whole or correctly allow for the waste land. One man of my acquaintance, realizing that fact, says that in looking over land for purchase he makes it a practice to go first where no timber is to be found. Better than that is some systematic arrangement that causes one to see a sample of every part, and travel in straight lines evenly spaced will do it.

So far our maps have been constructed on the scale of 4 inches to the mile, and 50-foot contours in the rough land with which we have to deal serve to represent the topography. In addition, as a result of the examination, timber maps are constructed showing the character of the growth and the amount of merchantable timber judged to be standing on the land. On these sheets the progress of the cutting can be drawn in succeeding years. These timber maps are of transparent tracing cloth, so that they can be laid over the topography and the two seen in relation. Lastly, since contour maps are not easily read by most woodsmen, topographical models are constructed out of cardboard or veneer. These are perfectly comprehended by any person. With their aid a contract can be let or plans of work talked over in the office with the same clearness as to main features as if men were on the land.

The survey and mapping of a township six miles square has ordinarily cost me about two months' work, two weeks in the office and six in the field. A township can be gone over conveniently from about four camps. If there are on the land places to live in the topographer requires the help of but one man.

POWER DEVELOPMENT AT NIAGARA FALLS OTHER THAN THAT OF THE NIAGARA POWER CO.

By W. C. Johnson, Member of the Engineers' Society of Western New York.

[Read before the Society, February 3, 1896.]

Within the past five years a company has been engaged in the development of water power at Niagara Falls, about whose operations much has been said and written.

The plan which this company was organized to carry out involved the construction of a long tunnel under the city for a tail-race, and the sinking of shafts into the rock to a depth of 150 to 175 feet in which to place its wheels.

This work was necessarily costly and many difficult problems arose in its execution.

The problems have been solved and the work executed in a manner which reflects great credit upon the eminent engineers who have made up the consulting board, and upon the able engineers who have had charge of the execution of the different parts of the work.

Those of us who have followed the progress of the work, as most of us doubtless have done, I imagine scarcely know whether to admire most the good judgment shown in the employment of engineering talent or the wonderful skill in advertising. The newspaper fraternity have turned themselves loose on this work. The adjectives "vast," "grand," "stupendous," etc., have been liberally thrown into every item, but not always with discretion.

One of the most glaring absurdities in connection with the mass of popular writing about this work has been the use of the phrase "Harnessing of Niagara," and the statements, in big headlines, that power would be turned on at Niagara on a certain date (which date was, by the way, several times changed), when the facts are that at the time when the first shovelful of earth was taken out in this work more water power was in use at Niagara Falls than in but few other places in the world, and by far the most powerful wheels in the world were in operation there.

Power at Niagara was turned on in 1725, and, during most of the time since, its force has been utilized to turn water wheels.

It is to these other and earlier developments that I will call your attention to-night.

The first use of power at Niagara was about 1725, when the

French erected a sawmill, near the site of the Pittsburg Reduction Company's upper Niagara works, for the purpose of supplying lumber for Fort Niagara.

In 1805 Augustus Porter built a sawmill on the rapids. In 1807 Porter & Barton erected a grist mill on the river. In 1817 John Witmer built a sawmill at Gill Creek. In 1822 Augustus Porter built a grist mill along the rapids above the falls. From that time to 1885, when the lands along the river were taken for a State Park, a considerable amount of power was developed along the rapids by a canal which took the water out of the river near the head of the rapids and followed along nearly parallel with the bank of the river.

Mills were built between this canal and the river and a part of the 50-foot fall between the head of the rapids and the brink of the falls was utilized. A paper mill was also built on Bath Island.

In 1847 Augustus Porter outlined the plan on which the present Hydraulic Canal is built.

In 1852 negotiations were commenced by Mr. Porter with Caleb J. Woodhull and Walter Bryant, and an agreement was finally reached with these gentlemen by which they were to construct a canal and receive a plat of land at the head of the canal having a frontage of 425 feet on the river; a right of way 100 feet wide for the canal along its entire length of 4400 feet, which is through the most thickly populated part of the city, and about 75 acres of land near its terminus having a frontage on the river below the falls of nearly a mile.

Ground was broken by them in 1853, and the work was carried on for about sixteen months; it was then suspended for lack of funds, and nothing more was done until 1858, when Stephen N. Allen took up the work and carried it forward for a time.

After that, Horace H. Day took up the matter, and in 1861 completed a canal about 36 feet wide and about 8 feet deep.

The location of the head of this canal was the best that could have been chosen. From the head of the rapids it is but a short distance to an island (Grass Island), which extends a considerable distance along the shore, and for a considerable distance above the island the water is very shallow.

In this short space, between the head of the rapids and the foot of Grass Island, the entrance of the canal was located.

Owing probably to the disturbed financial conditions occasioned by the War of the Rebellion, and other causes, it happened that no mills were built to use the water from the canal until 1870, when Mr. Charles B. Gaskill built a small grist mill on the site of

the present flouring mill belonging to the Cataract Milling Company, of which Mr. Gaskill is president.

In 1877, the canal and all of its appurtenances were purchased by Mr. Jacob F. Schoellkopf and A. Chesbrough, of Buffalo, who organized the Niagara Falls Hydraulic Power and Manufacturing Company, of which Mr. Schoellkopf is still the president.

Since that time the building of mills has gone steadily forward. The following is a list of the mills using water from the canal:

Central Milling Company use	1,000	horse power.
Schoellkopf & Matthews use	900	" "
Pettebone-Cataract Paper Co. use	1,300	" "
Cataract Milling Company use	400	" "
T. E. McGarigle, Machine Shops, use	12	" "
City Water Works use	155	" "
Pittsburg Reduction Company will use	3,000	" "
Cliff Paper Company use	2,500	" "
Will use in 1896 additional	300	" "
Niagara Falls Hydraulic Power and Manufacturing Company, use	280	" "
Rodwell Manufacturing Company, Niagara Silver Company, use	75	" "
Carter Crume Company use	39	" "
Francis Manufacturing Company use	10	" "
The Kelley-McBean Company use	5	" "
Oneida Community Co., Limited, use	300	" "
Niagara Falls and Lewiston Railroad use	150	" "
Will use in 1896 additional	350	" "
Niagara Falls Brewing Co. will use in 1896	250	" "
Total	11,026	" "

Mr. Porter's contract with Woodhull & Bryant only conveyed the lands to the edge of the high bank of the Niagara River, and did not include the talus or slope between the edge of the high bank and the river, and only granted the right to excavate down the face of the bank 100 feet.

At that time it was not considered that any higher head could ever be utilized, because it was not thought that wheels could be built to stand the pressure of a higher head; in fact, none of the mills attempted to use more than 50 or 60 feet head. For this reason it happened that although the capacity of the canal as at first constructed was sufficient for some 15,000 horse power its capacity was exhausted and only about 7000 horse power produced.

The flouring mills of Schoellkopf & Matthews, Cataract Milling Company, Central Milling Company, the Pettebone-Cataract Paper Company, the City Water Works, and the factory of the Niagara Wood Paper Company, which is not now running, leased

the right to draw certain quantities of water from the canal and constructed their own wheel pits, and put in their own water wheels.

Two different methods were adopted for constructing the pits for these various mills. In some cases a shaft was sunk in the rock at some little distance back from the edge of the bank, in which the wheels were placed, and a tunnel driven from the bottom of the shaft to the face of the bank for the discharge of the water after it had passed the wheels. In other cases a notch was cut into the face of the bank and the wheels placed in it.

In all cases turbine wheels of different makes, running on a vertical axis, were used.

In 1881 the Niagara Falls Hydraulic Power and Manufacturing Company put in a power plant for the purpose of supplying power to customers, delivered into their mills. The method adopted was as follows:

A shaft 20 x 40 feet was sunk to a depth of about 80 feet, and about 200 feet back from the face of the high bank; from the bottom of this shaft a tunnel was driven to the face of the bank for a tailrace. The water was conducted to the bottom of this shaft in iron tubes, and used on two different turbines running on vertical axes.

The power developed by these wheels—about 1500 horse power—was transmitted by shaft, belting or rope drive to various customers, all located within 300 feet of the wheel pit.

About a year ago a turbine wheel of a capacity of 600 horse power, running on a horizontal axis, was put in this same wheel pit, the power transmitted up to the surface by means of a manilla rope drive, and there used to run electric generators, from which power is being transmitted to various small consumers.

In 1886 the Niagara Falls Hydraulic Power and Manufacturing Company secured a deed of portions of the slope between the high bank and the river, and have since secured other portions, so that they are now at liberty to use this slope for mills and power houses. In this same year I was appointed engineer of the company, and have been in charge of all the improvements made since that date.

The advance in water wheel construction, and especially the development of the possibility of transmitting power by electricity, has made this lower slope one of the most valuable parts of their holdings.

In the spring of 1892 the Cliff Paper Company, being desirous of increasing their plant by adding a wood pulp mill, to use about 2500 horse power, leased sufficient water from the Niagara Falls

Hydraulic Power and Manufacturing Company, agreeing to take it from the tunnel through which water was discharged from the outlet of wheel pit just described, and I was employed to design and superintend the construction of the plant.

For the purpose of getting the machinery requiring the largest power near to the wheels, it was decided to build a mill on the lower bank near the water's edge, and to place the pulp-making machinery in it, preparing the wood on the top of the bank, lowering it down ready for grinding and elevating the product.

To divert the stream of water flowing through the tunnel and confine it for use in the new mill, a short tunnel was driven into the face of the bank at a point about 20 feet below and 12 feet to the left of the mouth of the old tunnel.

From the mouth of the new tunnel an iron pipe 8 feet in diameter was laid along the slope of the bank, connecting with the tube 10 feet in diameter in the basement of the lower mill. From this tube the water is brought to the wheels on the first floor. Provision is made for the discharge of water into the tunnel direct from the canal in case the discharge from the wheels does not furnish a sufficient supply.

Owing to the contracted channel of the river below the mill, there is an extreme fluctuation in the water below of about 30 feet, and it is liable to sudden changes. On this account the first floor, on which the wheels are placed, is set about 16 feet above the ordinary level of the water in the river, which is above the highest recorded rise, the remaining part of the head being obtained by the use of draft tubes.

It was decided to use two wheels to develop the required 2500 horse power and to couple the shaft of the water wheel to the shafts carrying the stones used for grinding the wood.

It was therefore necessary that the wheels should run at a speed of 225 revolutions per minute. This requirement, as well as the requirements of strength, precluded the use of any of the stock wheels in the market and made a special design necessary.

Under my plans and specifications the wheels were built by James Leffel & Company, of Springfield, Ohio.

The wheel runners are 66 inches in diameter. The bucket rings are made of a special quality of bronze. These rings are fitted to a heavy cast iron center with steel bolts; each ring supplied with twenty-four buckets, with the discharge opposite each other. The wheel runner is fitted substantially with keys to the wheel shaft, which is made of hammered wrought iron, finished diameter through bearings $6\frac{7}{8}$ inches, with a total length from center to

center of couplings of 17 feet. In order to prevent the wheel shaft from shifting endwise, suitable adjustable collar bearings are located on it, immediately on the inside of the elbow.

Surrounding the outside of the wheel runner are wheel cylinders, supplied with twenty gates. These gates are made of cast steel and designed to be as nearly balanced at all points of the gate opening as possible. They are mounted on steel gate bolts attached to wheel cylinders. Each gate is supplied with two side-rack arms, which arms are attached loosely to the two side-rack rings. These rings are mounted on the wheel cylinders, and are operated simultaneously by the movement of the gate shaft connecting to them with roller rings made of cast steel. The gate shaft is made of hammered wrought iron, passing through bronze stuffing boxes in the sides of the cylindrical case. One end of this gate shaft is operated by a suitable lever, with bronze nut, steel screw and hand wheel for same, carried in the heavy frame mounted on one of the elbows.

The work is contained in a cylindrical case 10 feet in diameter by 4 feet wide. The heads are made of heavy cast iron, with $\frac{3}{8}$-inch steel shell solidly riveted to them. On the top of the case is a large air chamber to assist in equalizing any irregularities in the flow of the water to the wheel. This air chamber is supplied with an air pump and glass water gauge, so that it can be cleared properly and filled with air when necessary. The case is also fitted with manholes and plates.

On the side of the case elbows are fitted, which are made of cast iron, being split through the center and bolted together, and where the wheel shaft passes through the elbows are stuffing boxes with bronze glands. Each elbow is fitted with manholes and plates.

On the discharge end of the elbows are fitted draft tubes which are each 18 feet long, made of $\frac{1}{4}$-inch steel thoroughly riveted and calked throughout. These draft tubes are substantially anchored to the foundation walls to prevent breaks or leakage by any movement. The wheel shafts, after passing through the elbows, are carried in heavy flat bearings, each 24 inches long, lined with anti-friction metal, bored to fit the shaft and supplied with ring oiling attachments, with large capacity of oil chambers at each end and on bottom sides of the bearings. The bearings are mounted on heavy cast iron bridge-trees, and are supplied with suitable bolts and adjusting screws, making a distance of 4 feet from the center of the wheel shaft down to the top of the steel beams.

The work is mounted on four heavy 20-inch steel beams, of

suitable strength and proportion for spanning the foundation walls, which are 14 feet 6 inches in the clear.

In 1892 the Niagara Falls Hydraulic Power and Manufacturing Company commenced an enlargement and improvement of its canal. The plan adopted was to widen the original channel to 70 feet and make the new part 14 feet deep. The canal is cut entirely through rock below the water line.

The power for driving the drills on this work was obtained from an air compressor run by water power from the power station and transmitted along the line of the canal in pipes. The excavation was done by dredges and the flow of water through the canal was not interfered with.

This improvement is now completed, and the canal has a capacity of about 3000 cubic feet per second, giving a surplus power, after supplying the old leases, of about 40,000 horse power.

Since this improvement has been completed a new power house has been commenced for the purpose of supplying power for tenants.

For this new plant water will be taken in an open canal from this hydraulic basin to a forebay 30 feet wide and 22 feet deep, which is now being built near to the edge of the high bank. From this forebay penstock pipes built of flange steel, 8 feet in diameter, conduct the water down over the high bank 210 feet to the site of the power house on the sloping bank at the edge of the water in the river below the falls.

The site of the power house was covered with broken and disintegrated rock which had fallen from the bank during ages past, which covered the bed rock to a depth of from 10 to 70 feet.

For the removal of this loose material a Giant or Monitor, as it is termed, was used. This is a machine throwing a stream of water from 4 to 6 inches in diameter, according to the size of the nozzle used, under pressure. It is very largely used in the Western part of the United States for mining purposes.

The water to supply this machine was taken from the canal, and the pressure of 210 feet head fall was sufficient to give a force which readily washed down all the loose material into the river, uncovering a bed of sandstone upon which the power house is built, and from which the material of which it is built was quarried.

The power house building will be 180 feet long by 100 feet wide, and will contain sixteen wheels of about 2000 horse power each. Only one-third of the length of the building is being constructed at present, it being intended to add to it as the demand for power arises.

The wheels in this power house will work under a head of 210 feet, which is the highest head under which water has ever been used for power in the quantity proposed in this plant.

The wheel which has been most used in the United States under high heads is the Pelton wheel, which is an impact wheel running on a horizontal axis. The use of the Pelton wheel was deemed inadvisable in this plant, because on account of the fluctuation of the water in the lower river, which is as much as 30 feet, it was necessary to place the floor of the station on which the generators were to stand about 20 feet above the ordinary water level, and, as it was desired to couple the generators directly to the end of the water wheel shaft, it was necessary to place the water wheels also at this elevation. This necessitated the use of draft tubes in order to obtain the full head available, which is impossible on the Pelton wheel.

It was necessary that the wheels would run at a given speed suited to the speed desired for the generators.

All of these conditions could not be met by any other construction than the turbine wheel, mounted on horizontal axes.

It was decided that water for the wheels should be supplied by a penstock leading from the forebay above described, vertically, about 135 feet to the top of the sloping bank, thence down the slope to the side of the station next to the bank, 8 feet in diameter, connecting with a supply pipe 10 feet in diameter, running horizontally along the center of the tailrace, from which the wheels would draw their water by connections from the bottom of the wheel case to the top of the supply pipe. In this connection, which is 5 feet in diameter, valves are placed so that any wheel can be shut down independently of the others. The wheels standing directly over this trunk discharge the water through draft tubes running down on either side of the supply pipe.

Several reliable builders of water wheels were asked to design wheels from my general plans and specifications, of which the following are the more important points:

"The wheels to be furnished under these specifications shall be horizontal in form, and figured to furnish 1900 horse power, measured on the shaft of the wheel, and to run at a speed of 300 revolutions per minute.

"The head under which these wheels will work will generally be 210 feet, but the wheel shall be figured of sufficient capacity to deliver 1900 effective horse power under a head of 205 feet, and all parts shall be of sufficient strength to stand the pressure due to a head of 220 feet without undue strain.

"The wheels shall be designed to take water directly underneath the bottom of the case at the center, and shall be provided with a supply pipe of such length as shall be specified on drawings hereafter to be furnished, which shall not exceed 2 feet below the periphery of the case.

"The case shall be supported on four 20-inch steel beams weighing 80 pounds per foot and 21 feet 6 inches in length.

"To these beams all the bridge-trees and the case shall be fitted and fastened.

"The beams shall be set such a distance apart and carrying the case so that the center of the shaft shall be at such a height above the top of the beams as shall be specified upon drawings to be hereafter furnished.

"The contractor shall guarantee all parts of the wheel to be of sufficient strength to stand the strain as above specified.

"He shall further guarantee the wheel to furnish 1900 effective horse power, measured on the shaft of the wheel when working under an actual head of 205 feet, and running at a speed of 300 revolutions per minute.

"He shall further guarantee the wheel to show a percentage of useful effect of not less than 78 per cent. at any point between full and three-quarters water under any head from 205 feet to 225 feet, and running at a constant speed of 300 revolutions per minute.

"He shall further guarantee a percentage of useful effect of not less than 60 per cent. under the same conditions from three-quarters to one-half water."

Under these specifications a contract was let to James Leffel & Co., of Springfield, O., for supplying the four wheels to be put in at present. The description of the wheels is as follows:

The wheel runners, in case of three wheels which are to run the generators of the Pittsburg Reduction Company, and which are to run at a speed of 250 revolutions per minute, are 78 inches in diameter; in case of the other wheels, which are to run at 300 revolutions per minute, 66 inches, the size being calculated so that a point in the periphery of the runner will move at a speed equal to about 75 per cent. of the theorètical velocity of water, due to the head under which the wheels are operating.

The rim of the runner is the bucket ring, and is cast solid from gun metal bronze. On this rim are two sets of buckets taking water on face and discharging at each side of the rim. The bucket ring is bolted to the spokes of a cast iron center, the hub of which is keyed to the shaft of hammered iron 20 feet in length.

Surrounding the outside of the runner is a cylinder in which

the gates are fitted. The gates are about 20 per cent. less in number than the buckets. They are hung on steel pins, and open by lifting one edge so that the direction in which the water enters the wheel is nearly tangential to the runner.

Each gate has two arms, which are connected to the rings, by means of which they are opened and closed.

This work is inclosed in a cylindrical case 11 feet in diameter and 4 feet long, which is connected to the penstock by a supply tube 5 feet in diameter.

On the side of this case elbows are fitted, to which the draft tubes are connected. The shaft passes out through these elbows through stuffing boxes. On the inside of these elbows lignum vitæ steps are fastened, against which rings on the shaft work to prevent end motion in the shaft.

To each end of the water wheel shaft will be rigidly coupled a direct current generator, capable of developing 560 kilowatts of electrical energy.

The beams upon which the wheels stand will be extended through underneath the generators, the whole to be fastened together and bolted firmly to the masonry foundations.

It is probable that regulation of speed will be secured by the following described device, though it is not fully decided:

The apparatus for regulating the speed of the wheels consists of a hydraulic piston, which applies its force in either direction to a rack which is connected with a pinion in the gate rigging of the turbine.

The force which operates the hydraulic piston is air, compressed under about fifteen atmospheres.

This compressed air is contained in a cylinder directly under the bed of the machine, and the pressure is maintained by a pump which constitutes part of the machine.

The pressure tank is about one-third full of a fine oil, and the piping is such that oil and never air enters the hydraulic cylinder.

There is a partition in the pressure tank, and one part of the tank is filled with oil and air under the pressure of fifteen atmospheres, and the other part of the tank is a vacuum.

After the oil has expended its force on the horizontal cylinder it is discharged into the vacuum end of the tank, and by the pump transferred into the pressure end. In this way a constant pressure and a constant vacuum are maintained. In other words, the oil circulates under pressure in a closed system without any access to atmospheric pressure.

The machine is provided with a high speed ball governor,

which actuates a balanced piston valve which stands in the circulating system. This valve has a lap 1-64 of an inch, and a motion of that moved one way or another as the speed varies throws the oil under pressure into one end or the other of the hydraulic cylinder, causing the rack to move so as to open or close the gates of the turbine, according as the speed is rising or falling.

The governor has an appliance by which the governing machine is checked before it has carried the gate too far open or shut, thus preventing racing, which has always been the difficulty with most machines devised for regulating the speed of water wheels.

The electric current generated in this power house will be conducted to the top of the high bank by copper conductors, carried up through an inclosed wire tower, and from thence distributed to the various consumers.

DISCUSSION.

Mr. Bassett.—Why is it necessary to place the wheels so far above the water level in the river and use draft tubes?

Mr. Johnson.—Because of the rise in the river during storms, which is sometimes as much as 30 feet; that is to say, the total variation between the extreme high and the extreme low water in the river below the falls is liable to be as much as 30 feet; that is, the water level is liable to vary as much as 15 feet either way from the ordinary level.

Mr. Bassett.—Why should there be such a rise at the falls when the rise at Buffalo is only about 5 feet during a storm?

Mr. Johnson.—The narrowness of the river below the falls near the Cantilever Bridge chokes the flow and causes the rise. The rise at Port Day, where the canal intake is, just above the rapids above the falls, is from 5 to 6 feet. The river at that point is probably a mile wide.

Mr. T. Guilford Smith.—What is the total amount of power proposed to be developed by the power companies at Niagara Falls by the plans now being carried out?

Mr. Johnson.—The tunnel already built by the Niagara Power Company has a capacity of about 100,000 horse power. They have the right to draw water from the river to the amount of 200,000 horse power, and I believe contemplate the possibility of constructing another tunnel. The present capacity of the canal of the Niagara Falls Hydraulic Power and Manufacturing Company is about 50,000 horse power, and can readily be increased to 100,000 or 200,000 horse power.

Mr. Smith.—What is the present capacity of your canal?

Mr. Johnson.—About 3000 cubic feet per second. If the canal were to be deepened this could be very materially increased. The canal is capable of development up to 100,000 horse power, or even 200,000 horse power.

Mr. Guthrie.—What is the estimated quantity of water that will be taken from the falls by these two plants when completed?

Mr. Johnson.—The grant to the Niagara Power Company says, "Water sufficient to produce 200,000 effective horse power." This language is about as definite as would be a deed of sufficient land to raise a certain number of bushels of corn annually. I suppose this grant would probably be construed to mean somewhere from 13,000 to 13,500 cubic feet per second.

The Niagara Falls Hydraulic Power and Manufacturing Company is at present using something like 1000 cubic feet per second, and if its plant should be increased to 200,000 horse power would use from 11,000 to 12,000 cubic feet per second.

Mr. Guthrie.—What effect will that have upon the falls?

Mr. Johnson.—The drawing from the river of the extreme quantity mentioned, it is estimated, would reduce the depth of water on the American falls about 3 inches, and on the Canadian falls about 11 inches. It is not likely, however, that this extreme quantity of water will be used for the next one hundred years or so, and, even if it should be, the slight changes in the depth would be immaterial when it is remembered that the difference in the direction of the winds is continually making a difference from day to day of some 3 to 6 feet.

Mr. Smith.—Are there not times now when the rocks in the river above the falls are out of water which at other times are covered?

Mr. Johnson.—Yes, sir; frequently.

Mr. Rogers.—Why did you say Pelton wheels were not adopted for your plant?

Mr. Johnson.—By using them we would lose about 16 feet of the head, as draft tubes cannot be used with Pelton wheels. This is the reason why the use of Pelton wheels was not seriously considered in this plant. I would not be understood to say that the Pelton wheels are necessarily the best for such a plant as this if it were not for the necessity of the use of the draft tube. The Pelton wheel is the only wheel which has been used successfully under extreme heads of, say, 500 to 1500 feet. Under 200 feet head I am not at all sure that the turbine wheel is not as good or better than the Pelton.

A Member.—Will the mills that take water from the canal continue to do so after the new plant is completed, or will they use electricity?

Mr. Johnson.—They will probably continue to run as they do now. This electric power is intended for supplying new consumers.

A Member.—What is the capacity of the power plant you are now building?

Mr. Johnson.—7000 horse power at present, with a contemplated increase to 20,000 or 25,000 by an extension of the same station.

A Member.—Where are the wheels being built?

Mr. Johnson.—By the Jas. Leffel Wheel Company.

Mr. McCulloh.—Have you any data upon the cost of excavating by the hydraulic excavator you used in preparing the foundation for the new power house?

Mr. Johnson.—I am not able to state the exact cost at present, as it was all day's work, done by the power company itself.

PAVING BRICK AND BRICK PAVEMENTS.

By H. J. March, Member of the Society.

[Read before the Engineers' Society of Western New York, November 9, 1896.]

HISTORY.

Brick have been in use in one form or another for a great many centuries. It is recorded that in 2247 B.C. the descendants of the sons of Noah said: "Go to! Let us make bricks and burn them thoroughly."

The Tower of Babel was built of well-burned brick. The mud of the Nile was the only material in Egypt suitable for brickmaking.

The plan was to make a bed into which were thrown large quantities of cut straw, mud and water, and this was tramped into pug, removed in lumps and shaped in molds by the hands. The molded clay was sun-dried, not burned, the bricks of Egypt being adobes. Contrasting this mode with that of to-day, it seems very crude indeed. Bricks, burned and unburned, were employed to some extent in the construction of the Great Wall of China, completed in 211 B.C. The credit of first burning bricks in kilns probably belongs to the Romans; but it is hard to fix the time of this improvement. The knowledge of the art of brickmaking has probably at no time become entirely extinct; but with the decline of Roman civilization it gradually expired, and was lost in Western Europe. The Romans made bricks extensively in Germany and in England.

During the reign of Henry VI brick construction was not very general, but under Henry VIII and Elizabeth the brick industry grew extensively. The fourteenth century did not see much brickwork construction, but in the fifteenth brickwork became common.

Up to the seventeenth century bricks made in England were of variable sizes. Charles I, in 1625, regulated the size considerably, and made them nearly uniform. In Holland and other provinces of the Netherlands, where no stone, except of inferior quality, is found, brick have been of universal use from the earliest times, the paving of streets and other public works being done with them. Hard paving bricks were made from a mixture of slime from the Haarlem Meer and sand. The celebrated Dutch Clinkers, or paving brick, were made at Moor from the slime of the River Yessel. In this country the New Haven colony was the earliest settlement in which brickmakers were recorded as a part of the population, and it is probable that in 1650 the first bricks made in this country were

burned by this colony. Brickwork became common here about the eighteenth century. Improvements in modes and machines for making common bricks received but little attention prior to 1840. Very little care was paid to the brick after they came from the kiln, the whole idea being to shape or mold them in some way. Consequently the bricks were light and porous, and absorbed a large amount of water; but modern brick machines have lessened materially these objections. We find bricks were first used for paving in this country about 1870, at Charleston, W. Va. This brick was simply common building brick, burned hard, resting on a board foundation. From this first use of hard-burned common brick for street pavement there has gradually grown the vast paving brick industry, common in our Western States particularly, fostered by the demand for a cheap, as well as a durable, pavement.

CLAY.

Paving brick in general are made from fire clay or shale, or both. The term clay is applied to the hydrous silicates of alumina, and has been produced largely by the decomposition of felspar rocks, caused probably by water disintegrating the binding material. The rocks containing a good proportion of oxide or salts of iron forming red clays, and those having but traces forming white or light clays. Pure clay has been found to be infusible even in the most intense heat, but when mixed with the alkalies or alkaline earths it becomes fusible in proportion to the admixture. Clays possessing a high degree of plasticity are termed long or fat, but when having little plasticity are termed short, meager or lean. In the parlance of the brickyard the first is called "strong clay" and the latter "weak clay." Strong clays absorb considerable water in tempering, and bricks made from these clays shrink materially in drying and burning. On the contrary, weak clays absorb but little water, and do not shrink either in drying or burning.

There are two distinct machines used in brickmaking,—namely, dry clay machines, using clay that has been dried by the sun and wind, and wet clay machines, in which the clay is worked in its moist condition as found in the bank. The stock from the dry clay machines is produced by the employment of molds to shape the clay. This product is more generally used for architectural purposes. The wet clay machine stock is used for engineering purposes, and is produced by forcing the plastic clay through a die in a continuous string, which is afterwards cut into bricks of required size. Bricks made by the former class of machines are far inferior as regards durability to bricks made by the latter machines.

I have read that some years ago in Washington, D. C., they had a costly proof of this fact. The invert of a sewer in which the first-named brick were used was entirely cut out by sand and gravel, and let fall a section of more than 700 feet in length. To confirm this statement I wrote to the Engineer Commissioner at Washington, D. C., and Captain L. H. Beach, assistant in charge of sewers, writes me that "our records show that the only case of sewer failure due to defective invert occurred in 1877, when a section of the North Capitol street sewer, about 245 feet in length, failed because brick invert was washed out. The kind or quality of the brick was not mentioned." However, what I have mentioned may be true in fact.

Analyses show that the best paving brick clays contain about 60 per cent. of silica, 20 per cent. alumina and the remaining 20 per cent. of iron, lime, magnesia, soda, potash and water. Alumina gives elasticity to the brick, although an excess of alumina is liable to produce checking or cracking in the kiln. The iron element should be less than 6 per cent. when necessary to subject a brick to high temperature. Lime is very injurious in a paving brick, and should not be in excess of 3 per cent., as it is changed in burning to caustic lime, which, when exposed to moisture, slacks, and consequently disintegrates the bricks.

The difference between fire clay and shale brick is not clearly defined. Generally speaking, fire clay bricks are of a light color, varying from all shades of yellow to almost white, due to the absence of iron and fluxing elements. They are capable of standing a heat of 2000 to 4000 degrees Fahrenheit. Shale bricks vary in color from a dark brown or red to a light gray, and possess more or less of a tendency to a laminated structure. They also contain about 8 per cent. of iron, which largely determines their color. Fluxes to the amount of about 5 per cent. are also a characteristic of the shale product.

In tests for compressive strength a great many shale brick are found to stand about 5000 pounds more than fire clay brick. This fact alone is not a material argument in their favor if it can be proved that such excessive compressive strength is not necessary for best efficiency, unless there exists correlatively a superior structure.

It would take too long to describe the process of manufacture through its varying degrees of preparing the clay, grinding, screening, tempering, molding, repressing, drying and burning. Suffice it to say that these several degrees in the process of manufacture should be mastered in all their detailed operations by the workmen, so that there would not be the slightest departure in their execution

day by day in order that a uniform product may be obtained. The greatest defect in the paving brick industry of to-day is the lack of uniformity in product from the same manufacturer. If manufacturers could be assured that all their brick could be made equal to the best that they had produced they would be supremely happy, not to speak of the joy that would come to engineers. Different clays demand different treatment, and all demand the closest attention as to operation before and after setting in the kiln in order to be assured of good results. I have recently heard of a new kind of paving brick, composed of common coal ashes and a few chemicals, which require no burning and are ready for use five hours after made. Generally speaking, freedom of method in operation should be accorded the several manufacturers, both for economy and efficiency. The finished products alone should be required to meet the standard of tests.

SIZE AND SHAPE.

Let us look at some of the finished products. They are of varying sizes, shapes and color. Other things being equal, the proper size and shape of paving brick should be determined primarily by the element of commercial usefulness; that is, they should not be so small as to cause an unnecessary large number of joints or to increase materially the time of laying them for pavement or for any other purpose. They should not be so large as to afford but little foothold for horses, although we may be approaching the horseless age. However, when all phases of the question are considered, it seems to me that the proper size for a paving brick is that of the ordinary building brick. Bricks of this size, when unfit for pavers, can then be used for building and other commercial purposes. This available secondary use, obtained by retaining likewise the same shape as building brick, renders them cheaper for each designed purpose.

Not a few brick advocates favor a brick with rounded top edges; others lateral projections and grooves, or a combination of both. However, my experience has been that a brick with rounded top edges presents a more attractive appearance in the pavement. These several features, large size, shape, etc., may have some advantages, but I do not think they are of sufficient importance to warrant their general adoption at the sacrifice of usefulness for other purposes. It is claimed by some manufacturers that a brick of the block form, on account of its large size, cannot be thoroughly and uniformly burned. This claim, in point of fact, I do not think is well grounded, although there is a limit of size. There is no impera-

tive demand for bonding brick together by special patented forms, simply because there is no great strain to be distributed over the impacted material that cannot be accommodated by the ordinary form of brick.

CHECKS AND CRACKS.

There are some brick that are full of checks and cracks, particularly cobweb cracks. These have been caused probably in the drying process, by drying too rapidly; or they may have been hacked in the wind or in a strong draft; or, again, they may contain too much alumina, to which I have already alluded.

END CUT AND SIDE CUT BRICK.

Brick are cut the desired size in two ways,—namely, the end cut and the side cut. The latter is more generally preferred, because when laminations occur in brick, as is the tendency of incomplete clay operations, they are found to be parallel with traffic, and hence less liable to chip. This has always been the belief until recently, when more complete tests by Professor Orton have evidenced the contrary. See *P. and M. Journal,* March, 1897.

REPRESSING.

Many persons claim that a repressed brick is far superior to what is known as the standard or square brick not repressed because it is claimed that repressed brick are rendered more nearly uniform in size and density and present a more attractive appearance. But if by so doing the clay perchance be too dry, the bond is broken and the structure changed; then repressing is undesirable. I am told by a manufacturer that repressed brick are harder to burn, and when burned are apt to be hard on the outside and soft in the center. Professor Orton's tests show that it is of great advantage to repress end cut brick because of condensing laminations, and of great disadvantage to repress side cut brick. See *P. and M. Journal,* March, 1897.

VITRIFIED BRICK.

The chemistry of burning, according to Chase, is at 100 degrees C. the water held in mechanical suspension is driven off. That held in chemical combination is driven off at a little below red heat. At a red heat the carbonates are decomposed, and organic matter is consumed. At a white heat vitrifaction takes place, and from here the kiln is gradually cooled. Professor Baker says: "Vitrified brick are generally very hard, and generally also equally brittle and unfit for a pavement. There may be clays which make the

best paving bricks when burned to vitrifaction, but the writer (Professor Baker) does not remember having seen any such." On the contrary, Mr. C. P. Chase, an engineer of Iowa, in speaking of defective brick in a pavement one year old, says: "There were not a large number, but sufficient to show that brick, no matter how hard or compact they are, will not do for paving unless evenly burned and vitrified." I have in mind one vitrified brick product which I have tested, the results of which are in accordance with Professor Baker's idea. It absorbed very little water, about one-quarter of one per cent.; was so very hard and brittle that it flaked off in chips when in the rattler, rendering its abrasion percentage very high. It had long been my impression that this brick was burned too hard; that is, too highly vitrified. Yet later tests show it to be very satisfactory. In correspondence lately with the manufacturer of this brick I found that the mixing had been decidedly more thorough, and that the time of burning had been reduced from eleven days to nine days, which undoubtedly accounted for better results. There may be clays that demand vitrifaction for best efficiency, but this is not true of all clays.

SALT GLAZED BRICK.

Does salt glazing improve paving brick? Many claim that it is done to cover up structural defects. Salt glazing, however, can only be applied to hard-burned material. If there be any great injury done by its use it is that caused by the natural dampness of the salt being imparted to the kiln when at a high temperature, thus suddenly cooling the bricks, thereby having a tendency to check or crack them. Salt glazed bricks would naturally absorb less water than others. But this is no great advantage over other bricks if their absorption is not excessive; that is, above what has been deemed reasonable, and is in harmony with other desirable qualities. Salt glazed brick, presenting a glazed surface as they do, are more slippery than others. Several manufacturers have informed me that they did not believe in salt glazing paving brick. I have herewith tabulated some information that may be of interest, sent me at my request by several manufacturers of paving brick.

STANDARD TESTS.

Let us now examine the structure further by a standard of tests. I do not think there is a more opportune time than this to emphasize the necessity for a standard of tests that may be uniformly adopted in every detailed operation, so that we may not only know the comparative value of different paving brick, but also

the probable durability of the same under such and such extent of traffic with given modes of construction. Hundreds of tests of paving brick have been made that are only of local value, because of the varying conditions governing them. We note with pleasure the progress in this line of the committee appointed by the National Brick Association for the purpose of outlining a standard of tests for paving brick, based on careful experiments. The tests that have been adopted by those who have given the matter special study are:

1. Lime test.
2. Specific gravity test.
3. Transverse test.
4. Crushing test.
5. Absorption test.
6. Abrasion test.

In the annexed table will be found these several tests as conducted by different authorities.

The necessity of tests to determine what kind of brick shall be used is conceded by almost all. There seems to be the greatest difference of opinion concerning the abrasion test. One writer deprecates the use of Quincy granite as employed by another in the abrasion test for comparison, because of the lack of uniform conditions. This is quite right in point of principle; namely, that no comparison of results should be made unless governed absolutely by the same conditions. Theories and arguments work out very nicely when based on given conditions. But let us first be sure that our conditions are given, are absolutely certain. For instance, the complete identification of the brick throughout all the tests, the correct weights, the use of similarly shaped scrap iron, or foundry shot of certain number of pieces, and of certain weight, and the same number of brick each time, the time and speed of running the same rattler,—all of these requirements make up uniform given conditions. These conditions of uniform tests can best be obtained by the municipality possessing a testing laboratory of its own, where materials and detailed operations of testing may be under the immediate care of the engineer in charge.

Of late there has been a tendency on the part of some to discard the absorption test, because it is claimed that any brick that will stand the rattler test will stand the absorption test. I think that the abandonment of this test would be an unwise procedure, for every test has its value which is of no little importance.

In reference to the absorption test I have found that out of ten different kinds of brick, there being two of each, in one set of ten

REPORTS FROM MANUFACTURERS.

ENGINEERS' SOCIETY OF WESTERN NEW YORK — H. J. MARCH, M.S., C.E.

	Name of Brick and Where Made.	Manufacturer.	Are your bricks: Fire Clay Only?	Shale Only?	Mixture?	Price, at works, per 1000 of Building Size: Not Repressed.	Building Size: Repressed.	Block Form: Not Repressed.	Block Form: Repressed.	Do you use: Dry Clay or Wet Clay Machines?	Up Draft or Down Draft Kilns?	Do you prefer paving bricks to be: Vitrified?	Square Edge?	Repressed?	Building Size?	Block Form?	Salt Glazed?	Capacity per Day.
1	B.	....			Yes.	$	$	$	$	Both.	Down D'ft.	Yes.	No.	No.	Yes.	No.	No.	20,000
2	B. R.	....	Two Kinds of Fire Clay.	10% Shale and Fire Clay.		8.00	8.50			Wet Clay.	Down D'ft.	Yes.	Yes.	No.	Yes.		No.	150,000
3	C.	....	No.	Yes.	No.	6.50	7.50	9.00	10.00	Wet.	Down.	No particular Choice, are Selling Mostly Block.					No.	150,000
4	E.	....		Shale.	Shale with 20% Com. Clay.	9.00	10.00	11.00	12.00	Direct from the Bank, Tempered to Stiff Clay.	Down D'ft.	Yes.	Beveled.	Yes.		Block.	No.	25,000
5	F.	....		Shale.			8.75			Wet.	Both Up and Down in Same Kiln.	Yes.	Yes.	Yes.		No.	No.	35,000
6	K.	....	For Fire Brick.	For Street Brick.			Yes.		Yes. 10.00	Stiff Mud.	Down.	Yes.	No.	Yes.	No.	Yes.	No.	30,000
7	M.	....	Both Fire Clay and Shale.		No.	7.00	8.00	11.50	12.00	Wet.	Down.	Yes.	No.	Yes.	No.	Yes.	**NO.**	165,000
8	Pk.	....	Yes.			9.00	10.00	15.00	16.50	Wet Clay.	Down.	Yes.	Yes.		Yes.		No.	250,000
9	Pn.	....		Yes.			8.00		10.00	Wet Clay.	Down.	Yes.		Yes.	2½ x 4 x 8.	3¼ x 4 x 8.	Never.	300,000
10	S.	....			Alluvial Clay.	10.00		Large 12.00		Wet.	Down.	Yes.	Yes.	No.	Yes.	No.	No.	70,000
11	Tn.	....			Yes.	15.00	16.00			Stiff Mud.	Up Draft.		Yes.	**NO.**			No.	20,000
	Average	....				$9.22,	$9.59.	$11.70.	$11.75.	Majority Wet Clay.	Majority Down D'ft.	Maj. Yes.	Maj. Yes.	Maj. Yes.	Maj. Yes.		All No.	110,455 Average.

the bricks were broken in halves, and in the other set the top, bottom and narrow end faces were removed for about one-half inch; that in this latter set the absorption percentage was higher in eight out of ten bricks than in the former set. The absorption percentage upon similar whole bricks was less than either, showing that the interior of the brick was more porous than the exterior, and also indicating, since this was with forty-eight hours' immersion, that twenty-four hours' immersion would have been too short a time for this lot of bricks, and I think in general for all brick, although, of course, the greater amount of absorption would occur in the first few hours.

I do not think there is any definite dependency of abrasion on absorption, save in maximum and minimum absorption there is generally the greatest abrasion; in the one case the bricks being too porous and soft as to wear away gradually, and in the other case being so hard as to flake off in considerable quantities. A study of the annexed graphic table of tests in which Medina sandstone was also tested for comparison will prove the foregoing assertion. In reference to abrasion, the difficulties encountered by the adoption of a standard of tests when departing from what has been the custom are at once apparent when one compares new results with former results, for there has been much of indefiniteness in tests everywhere. However, the way is to make the radical change if necessary when a standard test has been developed, and then all results may be justly compared. I do not think it advisable to use cast iron bricks or pieces of pig iron in the tumbling barrel, principally because a use of them causes a severity of results unwarranted and unfair when actual service in the pavement is considered. Again, tests are not so comparative as we think when under such conditions. Should abrasion percentages be compared one with the other, even in the same tests, where large iron blocks or pieces of pig iron are used when the chances exist of one brick being unduly pounded more than its neighbor? To show the effect of speed of revolution on results in practically the same sized and shaped barrel under practically the same conditions, except that of speed, the number of revolutions being practically the same, I have arranged these tests, made as follows, upon the same kind of brick:

RATTLER, THREE FEET LONG BY TWO FEET DIAMETER.

	Speed, 30 to 35 revolutions per minute.	Speed, 52 to 56 revolutions per minute.
	ABRASION, PER CENT. LOSS.	
First Tumbling	13.88 per cent.	7.28 per cent.
Second Tumbling, alone	4.66 per cent.	2.26 per cent.
Total of first and second Tumblings	18.00 per cent.	9.46 per cent.

It will be observed that with nearly double the speed there was only about half the loss, showing that with the higher speed the barrel went so fast as to carry the bricks with it, and in consequence there was less abrasion. Some one has suggested that the circumference of the tumbling barrel should be composed of the brick to be tested, laid close together, as in the pavement, and then subjected to the abrasion wear of scrap iron, etc. This idea has considerable merit in it, although it takes into consideration principally the grinding effect, necessitating a large number of rattler revolutions to get material results. In formulating standard tests it should be borne in mind that the object of tests should be to find the faults of a brick; that is, if it is porous, to what extent; or if it be brittle, to what extent, etc. An immersion of forty-eight hours is generally admitted to be sufficiently long to determine the absorptive value of a brick. Abrasion tests, in accord with the conclusions from experiments by Harrington and others, seem to approach very nearly to what is desired for a standard of tests in this line. I refer to these tests specially because most attention and importance have been given them.

PAVEMENT FOUNDATIONS.

Having now examined paving brick, let us look for a few minutes at the subject of pavements in general and their foundations, confining the discussion more particularly to brick pavements. There are a few primary elements essential to a good pavement, as mentioned by General Gilmore:

1. That it shall be smooth and hard, in order to promote easy draft.

2. That it shall give a firm and secure foothold, and not become slippery from use.

3. That it shall be easily cleaned, and shall not absorb and retain surface liquids, but discharge them quickly into the gutters and catch basins.

4. That it shall be noiseless and as free from dust and mud as possible.

5. That it should be readily taken up and repaired.

6. The roadway surface must be constructed of durable material.

These well-recognized requirements should be borne in mind when judging the efficiency of any pavement. The nature of pavements and their foundations in different cities is largely determined by the available material immediately adjacent to the localities, as the transportation of foreign material from great distances is quite

a large item in the first cost, and more or less so consequently in cost of maintenance.

CHOICE OF A PAVEMENT.

The choice of a pavement, after the above requirements have been considered, is dependent upon local conditions of grade, cost, etc., the popularity of home industries and, unfortunately, in some cities upon the ascendency of one political party or another. The relative rank of merit of different pavements, compiled from experiments and facts of actual service, is shown in the annexed tables.

It will be observed that brick stands in the front ranks, and surpasses asphalt in a majority of the requirements.

There are now about 200 miles of asphalt pavement alone in Buffalo, which amount represents about $10,000,000. Estimating brick at 30 cents a square yard less than asphalt, if it had been chosen by the people its use would have saved $1,000,000 in first cost, which at 5 per cent. interest represents $50,000 per annum. Supposing the cost of maintenance and durability the same, the question is, are the blessings of asphalt pavements so far superior to those of brick pavements to the amount of $50,000 every year? This suggestion, however, must be modified to this extent,—namely, that indefiniteness as to the efficiency of paving brick has in the past precluded its use. This indefiniteness is not so pronounced to-day as formerly, when the efficiency of asphalt was also questioned.

In New York City there is no great amount of brick pavement, and I find these remarks in the *Paving and Municipal Engineering Journal* for October, 1895: "In New York they have ten or more streets paved with asphalt where the grade varies from 2.5 to 6 per cent. One of these streets, with a 6 per cent. grade, was used in preference to parallel streets of less grades that were paved with blocks. Also traffic has deserted Ninety-third street, paved with granite, for an asphaltic pavement with a 6 per cent. grade in Ninety-fourth street. The granite pavement of Fifth avenue, between Thirty-fourth and Thirty-sixth streets, with 4.87 per cent. grade, has to be sanded for safety." In Syracuse I find James street has a grade of 7.3 per cent., and in Rochester Spring street has a grade of 5 per cent. and Clifton street 4.5 per cent. An investigating committee when visiting these cities was informed there was no difficulty in driving over the above-mentioned streets. In Buffalo I think the steepest asphalt grade is one of 5.10 per cent. on Utica street, from Main street easterly. Delaware avenue, from Forest avenue to the creek, has a grade of 4.40 per cent. Church street, from Pearl to Franklin, has a grade of 3.11 per cent.

RELATIVE MERITS OF PAVEMENTS.

FROM C. P. CHASE.

	Durability Under Traffic.	Cost.	Action of Elements.	Noise and Dust.	Repairs.	Service on Grades.	Health.
1	Granite.	Brick.	Brick.	Asphaltum.	Brick.	Granite.	Asphaltum.
2	Brick.	Wood.	Granite.	Brick.	Granite.	Brick.	Granite } equal
3	Asphaltum.	Sandstones.	Sandstones.	Wood.	Sandstones.	Sandstones.	Brick } equal
4	Sandstones.	Asphaltum.	Asphaltum.	Granite.	Asphaltum.	Wood.	Sandstones.
5	Wood.	Granite.	Wood.	Sandstones.	Wood.	Asphaltum.	Wood.

COMPARATIVE $\left\{\begin{matrix}\text{EASE}\\ \text{COST}\end{matrix}\right\}$ OF TRACTION ON DIFFERENT PAVEMENTS.

RUDOLPH HERING'S ESTIMATE.

Iron Rails	1	horse.	Good Macadam	8	horse.
Sheet Asphalt	$1\frac{2}{3}$	"	Cobblestones	7 to 13	"
Brick	$2\frac{1}{4}$ to $2\frac{3}{4}$	"	Ordinary Earth	20	"
Granite Blocks	$3\frac{1}{3}$ to 5	"	Sandy Earth	40	"
Wood	5 to 6	"			

COMPARATIVE MERITS OF PAVING MATERIALS.

AS USED IN CHICAGO.

Classified by D. W. Mead.

Relative Order of Merit.	First Cost.	Cost of Maintenance.	Facility of Repair.	Durability.	Freedom from			Absorption.	Foothold for Horses.	Ease of Traction.
					Noise.	Dust.	Decay.			
1	C. S.	B.	M.	B.	M.	A.	B.	A.	C. S.	A.
2	C. B.	G.	B.	G.	C. B.	B.	G.	B.	G.	B.
3	M.	C. S.	G.	C. S.	A.	G.	C. S.	G.	M.	C. B.
4	B.	A.	C. S.	A.	B.	C. B.	M.	C. S.	B.	M.
5	A.	C. B.	C. B.	C. B.	G.	C. S.	A.	M.	C. B.	G.
6	G.	M.	A.*	M.	C. S.	M.	C. B.	C. B.	A.	C. S.

* This, I think, is improperly placed last, as recent modes of repair have decidedly lessened time and expense of its repair.—H. J. M.

NOTE: A.—Asphalt. B.—Brick. C. B.—Cedar Block. C. S.—Cobblestone. M.—Macadam. G.—Granite.

Delaware avenue, from North street southerly, has a grade of 2.83 per cent. In Buffalo we have endeavored to avoid as far as possible making grades of asphalt pavements greater than 3 per cent. Some asphalt pavements of 4 to 7 per cent. grades may not be difficult to travel over if the weather is warm and high temperature has softened the asphalt so as to afford a foothold for horses, but in winter and with rainy, freezing weather I have seen drivers forsake an asphalt of 0.4 per cent. grade for a stone pavement. A brick pavement, because it will not wear smooth or polish, as do some stone pavements, will permit the use of any grade that may be desired.

UNDERGROUND IMPROVEMENTS.

The first consideration for a good pavement is the question of assurance that all main sewer, water, gas and other pipes or conduits and lateral house connections are in good condition as regards quality and trench settlement. Too much attention cannot be given to these underground improvements. The second important step is that all pavements, of whatever nature, should be laid in good weather and under all other favorable conditions as may be obtained. The street should be graded two feet wider than width of paving to proper grades, and sub-grades conformable to proposed crown of finished pavement. Soft or spongy places, not affording a firm foundation, should be dug out and refilled with good earth, broken stone or other equally good material, well rammed. The sub-grade should be thoroughly rolled with steam roller not less than five tons weight. No ploughing for rough grading should be done within 3 inches of the sub-grade.

DRAIN TILE.

Unless a sandy or gravel material exists, as the street grading progresses, a 4-inch porous drain tile, with open joints, to be covered with broken stone, should be laid on each side of the street back of the curb, in straight line and true grade, about 24 to 30 inches from top of curb to top of tile, so that water may be prevented from reaching the foundation of pavement. If the street has a heavy descending grade, then the use of drain tile is unnecessary. I find that a great many cities do not use drain tile, but we find in Buffalo that its use is of great advantage to the life of a pavement.

CURB.

The curb, which should be good, hard stone not less than 4 inches wide and 18 inches deep (preferably 6 inches wide and 12

inches deep), and not less than 36 inches long, dressed evenly, should be set in concrete or sand, backed by 6 to 8 inches of same material, care being exercised to set it in true line and grade. At the end of each curb, when set in sand, should be placed a small stone at the base, to prevent curb from being forced out of line. Upon the finished sub-grade shall be placed the foundation course of prescribed material. An examination of the table of comparative construction and cost and efficiency of brick pavements in various cities,—fifty-five in number,—which I have compiled from information sent me by several city engineers, will reveal the customs employed for a foundation course, as well as many other items of interest in pavement construction.

FOUNDATION COURSE.

Some use sand, others gravel; others furnace slag, others an under course of brick laid flat; others broken stone, and others concrete of varying thickness, dependent upon traffic. A concrete base has been generally recognized as the only permanent base. Its use may be quite desirable and altogether wise in the case of wet, spongy land that requires a well-bonded bed over which may be distributed heavy loads that may come upon it, to relieve the immediate local effect; but for sandy gravel soils and those of stiff clay, and where traffic is not extremely heavy, a concrete base does not appeal as the most economic and efficient one. There is quite a difference in broken stone, say at $1.30 a cubic yard, and concrete at $3.50 a cubic yard. Some of the best pavements in Buffalo have a 6-inch to 8-inch broken stone base. Again, concrete is not entirely stable, for its movements have caused much disturbance and no little expense to restore to the rightful place where the upheavals and cracks in asphalt and brick pavements particularly have been experienced.

From experiments in England by Geo. R. Strachan, A. M. Inst. C. E., in which a strip of concrete 6 to 1 ballast, 52 feet long, 12 inches wide and 3 inches thick was laid on sand to allow freedom of movement under a shed with open front, so situated that the sun did not touch it, and another strip 26 feet long, same width and thickness, 3 to 1 pebbles, and a third of the same dimensions, 3 to 1 sand, were also laid under the same conditions. The only movements that he discerned at the end of the month was a slight contraction in length in all the samples. He further says "that the uniform experience of concrete under asphalt is that cracks occur which would tend to show that contraction, not expansion, was the rule." These cracks in asphalt are not wholly due to the concrete

8

movement, as here in Buffalo, where some experimenting with asphalt has been done, cracks are so numerous that it would be absurd to ascribe the cause to movement of the concrete, the nature of the asphalt and its manipulations being responsible for such effects. Where the expansion of concrete has been experienced it has been attributed to the action of temperature. Curbing that has on one side asphaltic sidewalk and on the other asphalt roadway has been forced out of line toward the center of the street by the expansion of the concrete pushing respectively the top one way and the bottom of the curb the other. In our city of Buffalo we have had no little experience with concrete raising up asphalt pavements, particularly as though a root of a tree had grown underneath.

These effects have not been more generally experienced because mastic asphalt, being elastic, and binder coating, when used, have regulated more or less the movements of the concrete. Although Mr. Malo, the French authority on asphalt pavements, states that the cracking of asphalt pavements is largely due to the use of oils in fluxing and softening the mixtures, and deprecates the use of petroleum or other similar oils for such purposes, many engineers believe that it is due to the laying of asphalt pavements late in the fall and subject to variable weather, and, second, to not removing all moisture from the concrete before the asphalt is laid.

The expansion of concrete, I think, as well as the expansion of brick and the cement filling, has been to some degree the cause of the complaint that has come from cities in reference to the rumbling noise and cracking of brick pavements. The concrete course, as well as the brick course, has arched or shoved up, leaving hollow spaces that cause the rumbling noise, intensified, of course, by the very nature of brick itself.

CUSHION COURSE.

On top of the foundation course for brick pavements a sand cushion is generally placed. In different cities this ranges from ½ inch to 2 inches in thickness. Where the top surface of the concrete is left rather rough I think a 2-inch cushion should be employed to take up in some degree the movements of the concrete and to offset inequalities of brick. In reference to the efficiency of a sand cushion, it certainly is not perfect, especially with a broken stone base, as in some cases it has worked down between the pieces of stone; and because of this one writer deprecates the use of a broken stone base. A desirable cushion would be one of an elastic nature. Sand does not meet this requirement, and yet it seems to be the only practicable cushion.

SELECTION OF BRICK BY COLOR.

For the selection of brick to be used in the pavement there seems to be no definite guide. The kind of fuel used in burning will affect the color, not to speak of the constituent elements of the brick itself. I have made tests of brick where the varying colors of the same product were particularly noted, and no special difference in absorption and abrasion was observed except in extremes. Very dark-colored brick are generally overburned, and, being too hard, are liable to chip off in fragments, while pale, very light-colored brick, being underburned, are not as tough as others. These conclusions are operative upon different-colored brick of the same product, and not upon different products. Generally speaking, the medium-colored brick of any product are the toughest and most durable. Again, that kind of brick is best for paving purposes which when broken reveals a close, homogeneous structure of uniform color, the break being a clean, sharp one.

After the selected brick have been laid with proper crown (which should be parallel with the crown of foundation course and roadbed), and at right angles to the curbs, breaking joints evenly, they should be rolled with a steam roller and all cracked or broken brick replaced by good, whole brick. In reference to the crown of a brick or stone pavement, it is advantageous that it should be lower than the curb grade, so that in the future, after the brick pavement has served its time, it could be surfaced with asphalt if competition with brick pavements should so lower the price of that material that its use would be cheaper than to supply new brick where needed.

FILLING OF JOINTS.

The question of filling joints now presents itself. Some cities have experienced no little trouble in the use particularly of neat cement, and also of a composition for joints. Sand filling is employed in some cities, but the liability of water percolating through the joints and causing trouble has undoubtedly limited its use. However, there has been no special complaint from cities where it has been used that can be traced definitely to this cause. Coal-tar pitch and asphaltum pitch have been used also for filling of joints. The joints of brick pavements laid in Buffalo in 1892 were filled with pitch; but this was abandoned in 1893, cement grout being used since then. The pitch under high temperature softened, and consequently was more or less of a nuisance to passing vehicles.

In Newark, N. J., fire-clay brick were laid in December, 1895, at a temperature below freezing point, cement grout being used

with salt to fill joints. The brick raised, due to supposed expansion of the brick, and resulted in more or less rumbling noise when vehicles passed over. At the same place a brick pavement laid in warm weather, the joints being filled with Portland cement, the rumbling noise has also been experienced, but not to such a large extent as that from pavement laid in cold weather. The Newark authorities are thinking of abandoning the use of cement filling for pitch mastic. Experiments are now in progress there with a combination of both; that is, spaces for 15 feet at intervals across the full width of pavement and for one inch along the curb being filled with a paving mastic, the remaining space being filled with cement grout in the hopes of counteracting the expansive power of the cement.

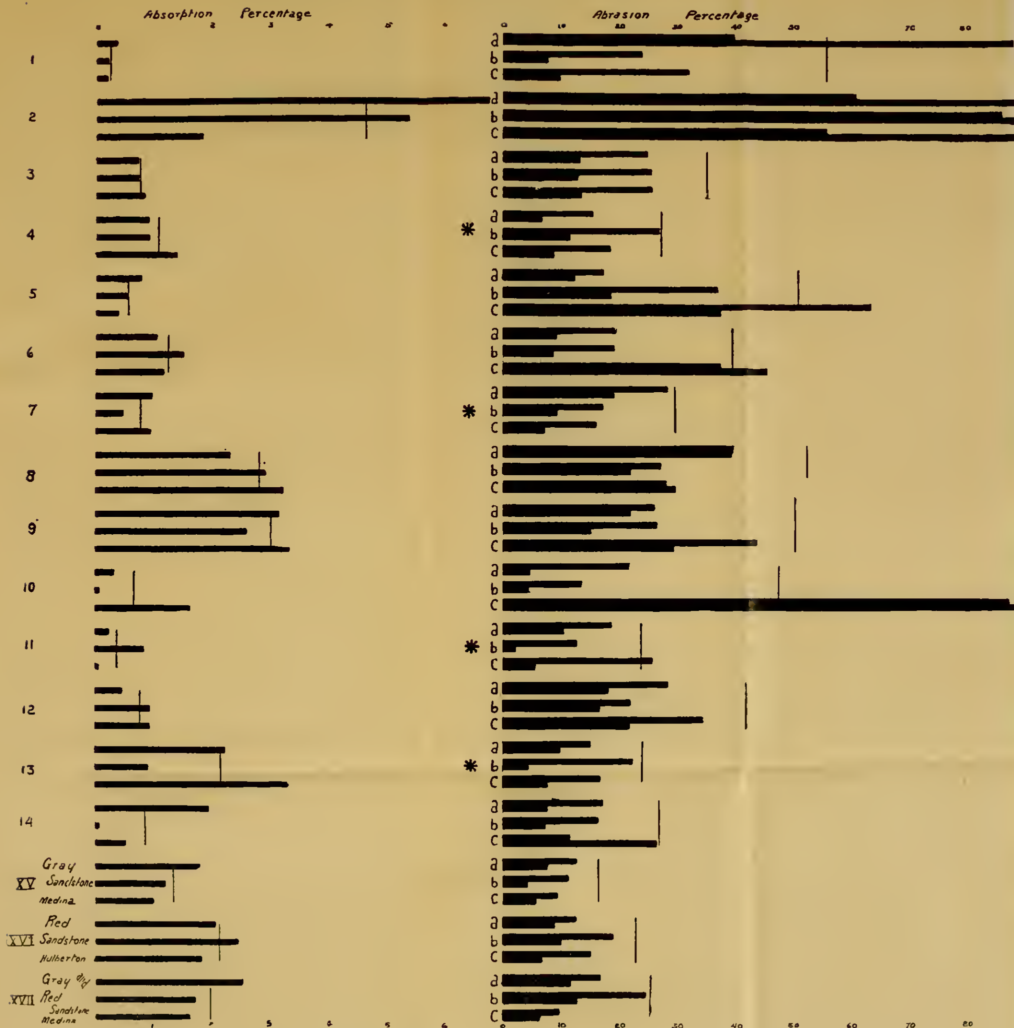
In Cortland, N. Y., where pitch and cement were both employed, the cement in setting within three days forced the pitch out of the joints. This cement had been tested previously for expansion. After the cement had set the expansion seemed to cease.

In Brooklyn, N. Y., on the McDonough street pavement, where they were troubled by a rumbling noise, the bricks having arched up, a 15-ton steam roller was used in the hopes of breaking the joints. Then a brick or two along the curb was taken out, but even this was of no avail. The theory is that when work was in progress the temperature fell 10 to 15 degrees and froze the sand and concrete. I think that it has now about been decided to remove the brick, so great has been the complaint against its rumbling noise, and lay asphalt on the concrete foundation. This step, if it be taken, will be greeted with joy by asphalt advocates. The above theory, however, as to the cause of such disturbance is contradicted by the experiences in Newark, N. J., to which I have alluded.

On South Sixth street, Terre Haute, Ind., a pavement of Canton brick laid about five years ago gave trouble by rising up in several places. Its construction extended into the winter, and was completed early the following spring. The brick were laid close on broken stone foundation on 2-inch cushion of sand, the joints being filled with Murphy grout.

In Easton, Pa., on account of an 8 per cent. grade, the joints near the gutter of a brick pavement were filled with cement grout for a width of (2 feet in report of city engineer of Easton) 4 feet from the curb, the remaining part being a sand filling. This resulted in a ridge of one-half to three-fourths of an inch in height along the division line between the cement grout joints and the sand joints.

COMPARATIVE TESTS OF PAVING BRICK



Bricks previously dried on furnace 94 hours, then immersed 48 hours.
The vertical black line shows the average absorption.
Three bricks, a, b, c, of each kind were tested.
Numbers 1 to 14, inclusive, were bricks.
Numbers XV, XVI, XVII cut to brick size—Medina sandstone.

The bricks were first tumbled for 1 hour, the loss in which is shown by the upper line.
The bricks were then tumbled again for 2 hours, the loss in which is shown by the lower line.
The average total loss is shown by the vertical black line.
In the first tumbling 112 pounds scrap iron and 120 pounds pig iron were used.
In the second tumbling 112 pounds scrap iron only were used.
Rattler 3 feet long by 2 feet diameter, 30 to 35 revolutions per minute.

* These brick selected as acceptable.

wit
of
vel
wa
rur
ext
aut
pit
nat
ful
wit
gro
cer

em
out
exp
cea

the
up
joi
thi
the
cre
bri
an
tak
the
by

tor
sev
cor
bro
fill

ne
fo
from the curb, the remaining part being ... sand ... g
resulted in a ridge of one-half to three-fourths of an inch in height along the division line between the cement grout joints and the sand joints.

In Wilmington, Del., where they were troubled with a rumbling noise, a strip in the center, 100 feet long and 18 inches wide, was removed, but this afforded no relief.

In Buffalo we have not been troubled seriously by any such bad effects. Dart street, paved in October, 1892, with pitch filling in joints, the brick laid close on concrete base, has one place where there is a rise of about 4 inches for three-fourths of the width of pavement. This is probably due to concrete expansion. Also in 1892 Oakdale place, with cement joints, laid by *private parties,* has bulged up in three or four places to a very small extent. The general condition of the street is good, although I understand a common cement was used for filling joints.

Penfield street, paved in May, 1893, cement joints, has some longitudinal cracks, due in this case probably to water getting under pavement from frozen water pipes, as well as to cement expansion.

Roos alley, paved in October, 1894, has some brick cracked longitudinally in a few places and depressed where repaired below general surface, caused probably by gutter in the center and cement expansion and concrete movement, and also trench settlement.

Laurel street, paved in 1895 and 1896, cement joints, laid by *private parties,* has some small longitudinal cracks, probably due to cement expansion.

Ada place, paved by *private parties* in the fall of 1894 and spring of 1895 with an American Portland cement composition, in the proportion of one of cement to six of gravel, has now about eighteen cross cracks and two or three longitudinal cracks. These, however, are no discredit to this particular cement, for I believe it to be of high quality, and I understand its expansive power is very slight. A defective sub-soil, together with whatever little expansive power the cement might possess when provoked by the elements, would be responsible for the above effects.

The annexed table of brick pavements in Buffalo gives special information concerning length, yardage, cost, etc.

From the foregoing instances we have seen that trouble has been experienced from brick pavements of fire-clay and also shale structure, not only on a concrete base, but also on a broken stone base, and where neat cement and also cement grout and pitch have been used for the filling of joints. Brick pavements laid in warm weather have given forth a rumbling noise, although not to such a great extent as those laid in cold weather. Cement grout, where used in Buffalo, as in most other cities, has been proportioned 1 to 1, and as used thusly one barrel of English or German Portland cement covers about 40 to 50 square yards, at an average cost of 13

cents a square yard for sand, cement and labor, the amount covered depending largely on the size of brick used. The expansive power of cement when used should be little or none, as therein is the disadvantage of its use. Coal tar and asphalt fillers have the disadvantage of softening up in warm weather and running off from the brick, particularly from the center to the gutters, leaving the edges of the brick exposed to immediate abrasion. Sand as a filler, as well as paving mastic, are considered detrimental to the life of a brick pavement because also of exposing the edges of the brick.

The combination of cement grout and paving mastic has not been sufficiently long in use to judge of its efficiency. What is known as Murphy's grout has been used for filling joints in some cities with considerable success, at an average cost of 16 cents a square yard. It is chiefly composed of iron slag and carbonate of lime, clean, sharp sand being added in proper proportion when used on the street. This grout is very hard, and consequently protects the edges of the brick; but does not accommodate itself, as far as I can learn, any better than other fillings to brick and cement concrete expansion. When a filling is harder than the brick the expansive power of the brick and cement tends to crack and upheave the brick. When a filling is softer it wears away, leaving the edges of the brick exposed to wear. What is needed is a hard, elastic filling that will accommodate itself to brick and cement expansion and concrete movement, and which will not soften materially under increasing temperature.

DURABILITY OF BRICK PAVEMENTS.

As to the durability of brick pavements one engineer put their life at ten years; another said in 1891 that many were in good condition that had been down fifteen years, and several over eighteen years old were giving satisfaction.

Prof. Ira O. Baker, in his pamphlet on brick pavements, gives considerable information, based on experiments, as to their durability. In Buffalo, for instance, on Main street, near Swan street, pavement width 56, he estimates that with a total daily tonnage of 2613, or 0.83 ton per vehicle, making a tonnage of 47 per foot of width, that 100 per cent. of sample brick No. 6, the best in the test, would wear away in 226 years, and sample No. 10 in 25 years.

And in New York City, on Broadway, near Pine, pavement width 40 feet, with a total tonnage of 10,905, being 1.39 per vehicle, making 273 tons per foot of width, sample No. 6 would lose 100 per cent. in thirty-eight years and sample No. 10 in four years. Of course, this durability considers the effect of traffic only, which,

however, is the most important item. Again, a pavement would not be of practical use during this period of 100 per cent. wear unless all brick could be worn down equally at the same time, which would be impossible. Experience has proved that a brick pavement shows more wear due to the abrasion of the edges in the first year than it does in the next six years. From my own tests of abrasion as indicative of durability, I have found the best paving brick equal to ordinary Medina sandstone. The best brick in the tests by Professor Baker was found equal to Quincy granite.

So far I have endeavored to present a fair, impartial and just consideration of the question of paving brick and the construction of brick pavements as now in progress in various cities. I have avoided as far as possible laying stress upon any particular merit or merits that a brick pavement may possess.

But let us look for a few minutes at some of the advantages claimed for brick pavements. They have been tersely enumerated by W. P. Judson, C. E., as follows:

1. Less first cost than sheet asphalt, which is its only competitor.

2. Less ultimate cost, as few repairs are needed if good brick are used.

3. Ease of construction and repair.

4. Ease of traction and of cleaning, and freedom from dust and mud.

In reference to the first advantage stated, it is conceded by nearly all that brick and asphalt are the great rival pavements. The less first cost is conceded by asphalt advocates.

In regard to the second advantage, less ultimate cost, it is claimed by asphalt advocates that owing to the short life of brick, its brittle and friable nature when subjected to traffic, makes it more expensive ultimately. Some paving brick that have been manufactured have undoubtedly warranted this conclusion, but such brick are far from representative of the character of paving brick in general.

The third advantage of brick—namely, ease of construction and repair—is self-evident, although it must be admitted that asphalt is now repaired by the aid of modern improvements with considerable more ease than formerly.

For ease of traction on the general run of grades asphalt is superior, as well as in cost of traction. I beg to differ with Mr. Judson also in regard to the ease of cleaning, although in street cleaning contracts brick is classed with asphalt. Again, for better freedom from dust and mud, asphalt ranks foremost. But this is

not a decided advantage, for there is just so much dust and mud from adjoining unpaved streets, etc., which must be distributed somewheres, and, if not upon the asphalt pavement, the dust is blown into abutting houses. Whereas with brick pavements, if the joints are a defective element in them, then these joints would receive the dust and dirt, which ought to be frequently and regularly collected by the street cleaning department.

In point of noiselessness, which Mr. Judson does not mention, some brick pavements as have been constructed are far inferior, and in general they produce more noise than asphalt. I will also add that brick is not materially affected by moisture or fire, as is asphalt, and therefore brick is superior in these respects.

In conclusion, it is not wise, nor is it just, to determine the efficiency of any pavement by casual impressions, such as comfort of riding, pleasing appearance, etc., for there are many considerations, as we have seen, besides these items already mentioned that should determine the efficiency of a pavement.

If I have prompted you to think with favor of paving brick, from the clay bed through their development of manufacture to a material of engineering usefulness in affording a cheap and durable pavement, when properly laid, for hundreds of cities that through their use only can enjoy the blessings which come from well-paved streets, I shall have accomplished a great deal in writing this paper.

DISCUSSION.

Mr. Ricker.—I would like to ask Mr. March if he is familiar with the brick pavement on the principal street connecting Dunkirk with Fredonia?

Mr. March.—I have information from Dunkirk in the list of cities in reference to foundation course, etc.

Mr. Ricker.—I have had very little experience with pavements, but this is a particularly disagreeable and noisy pavement; riding over it is exceedingly disagreeable on account of the noise.

Mr. March.—That seems to be the great trouble in a brick pavement. It is so sensitive when riding over it that vehicles produce a rumbling noise.

Mr. Mann.—I can answer in part. In some of the streets in Dunkirk they laid water and gas pipes and sewer lines just prior to laying the pavement, and undoubtedly the earth has settled away under the concrete, consequently we hear the rumbling noise along the line of the trenches; the concrete holds the pavement up, and it is hollow underneath. There were transverse cracks across the street. What caused this transverse cracking nobody knew.

Mr. Guthrie.—In Chicago there was a discussion on this

point with reference to Brooklyn, Newark and Syracuse also. Some of this rumbling sound is caused by hollow places, the earth settled away and the sand cushion being washed away through expansion of the concrete.

Mr. March touched upon the question of the uniformity of brickmaking; I do not believe we have uniform brickmakers. It is necessary to see that they are more uniform in their making of brick for paving, as I think if the same method of making is used by all makers good results may be reached and certain benefits got by standardizing the tests.

As to the disagreeableness of riding over brick pavements, it seems to me so many joints cannot but make riding in light buggies disagreeable in consequence of striking so many joints.

Mr. Green.—What material has been selected so far as a standard for hardness?

Mr. March.—Professor Wheeler has a formula in which he uses H. for hardness in the mineralogist's scale, brick value 6-½.

Mr. Green.—What material is used as a standard, as I understand the paving brick is tested by a grinding machine which is simply an emery wheel, taking a brick of some standard material and grinding the brick for hardness?

Mr. March.—Granite. An engineer of Peoria, in contradicting Professor Baker relative to the use of Quincy granite, said he had some granite he had tried to have cut down to a regular-sized dimensioned cube, but he found it was almost impossible to get it cut down to the required size and shape. However, Professor Baker uses Quincy granite for comparison, because, granite pavement being the hardest known pavement, any brick that would be equal to that in comparison is suitable for pavement.

Mr. Green.—Granite varies so much in composition and amount and size of the materials which compose it, and in the amount of quartz and other material. Though granite is used in pavements, it would not be used for a comparison for cements.

Mr. March.—Here in Buffalo we do not use granite, but Medina sandstone, cut down to the same size as the brick, is put in the same barrel with the brick. Our desire is to get a comparison between the brick and sandstone.

Mr. Green.—That brings up the same question, which sandstone?

Mr. March.—Gray and red mixed. Gray sandstone is the hardest; it has proved to be in tests.

Mr. Green.—One standard of materials for hardness is quartz, but granite is a conglomerate of very different substances, and I do not see how that can be used as a base or standard.

Mr. Ricker.—Do you have very much trouble with pavements on account of the foundation?

Mr. Mann.—Bad underground work will ruin any pavement.

Mr. March.—This has been found to have been the ruin of parts of pavements.

Mr. Ricker.—I remember when I was a boy in England that when paving one street they must have gone down five or six feet for the foundation for a block pavement of some stone similar to Quincy granite.

Mr. March.—In laying some pavements we have gone down four or five feet.

Mr. Norton.—I have seen some places where it was necessary to go that depth. The future importance of paving brick is a question resting both with the engineer and with the manufacturer. It would be well to have some uniform standard and uniformity of test which the makers may be prepared to meet; after the engineer has done that, his scope is over. Investigation necessarily must be founded on a standard. This we have found in brick pavements within the last few years.

Niagara Falls has had trouble, as I understand it, not so much in the rumbling and upheaval as in the character of the base and filling for the pavements. I do not see how it is possible to use a broken stone base with a sand cushion without losing all of the sand between the broken stone; the sand will be washed into the spaces between the broken stone used in the foundation, leaving the surface in very bad shape. It is necessary, however, to level up the foundation to get a uniform base upon which to lay the brick. From my own experience I do not think it possible to roll unequal brick to a true surface on either a 1 or 2-inch cushion. They must be sorted or sized in laying. On a street on which we were using a 1-inch cushion of sand this season there came on a heavy rain, and the water ran down from the center to the gutters and washed the sand away, and the brick had to be relaid.

Mr. Mann.—Because of the broken stone base?

Mr. Norton.—No. It was on a concrete base.

Mr. Ricker.—The sand was washed crosswise into the gutters?

Mr. Norton.—It was washed from the center to the side, through the joints, which necessitated taking up the pavement. Small depressions showed along the center of the street after it was cemented; when taken out the sand was found to have been washed out by the rain. It does not seem possible to use sand with broken stone without losing all of the sand filling. In the matter of the

STREETS PAVED WITH BRICK IN BUFFALO N.Y

WHEN LAID YEAR	MONTH	STREET	FROM	TO	CONTR	FILLING OF JOINTS	LENGTH	WIDTH	SQUARE YARDS	TOTAL COST	CONTRACT COST PER SQ YD	KINDS OF BRICK	TRAFFIC	CONDITION NOV 1 - 1896
1889		Coe Pl	Main	Ellicott	Private Prty		576	15	974			Common	Light	Poor Edges Chipped
1891	Oct	Purdy	St R R Co	Puffer	[illegible]	[illegible] Tile	775	24	2067	$ 5154	2 47	Syracuse	Medium	Edges Chipped
1892	Oct	Clay	Austin	Mily Rd	"	"	1110	28	3466	9881	2 85	"	Medium	Edges Chipped Gen'l Depression from Main Sewer
	Oct.	Danforth	Forest	Bradley	"	"	799	28	2437	7099	2.85	"	Medium	Edges Chipped
	Oct	Dart	Forest	Bradley	"	"	796	30	2654	7754	2 92	"	Medium	Edges Chipped At about 100 ft. from Bradley there is a rise of 4" abt 3/4 of the width
	Oct	Tryon Pl	Auburn	Forest	"	"	3220	26	10743	31357	2 92	"	Medium to Heavy	Edges Chipped
	Oct	Oakdale	Seneca	South End	Private L K Svor	Cement Jts	428		1238			McMahon Porter	Light	Generally Fair 3 or 4 Bulges where pavement [illegible]
1893	Sept	Barry Pl	Bird	Forest	PBM Naughton	Drain Tile Cement Jts	442	30	2140	6257	2 92	Syracuse	Medium	Good
	July	Eastwood	Main	Humboldt	Buf Pav Co	Cement Jts	1136	24	3083	9542	3.09	"	Light	Brick uneven top surface Edges Chipped
	Sept	Franklin	Church	Niagara	Queen City Paving Co	[illegible] Cement Jts	537	34 33	2796	6400	2 29	Franklin	Heavy	Generally Fair Some soft brick
	July	Gatchell	Broadway	W S R R	PBM Naughton	Drain " " Cement Jts	1446	24	3858	11219	2 90	Syracuse	Light	Good Many Joints open 1/4 inch along center
	May	Hawley	Forest	Letchworth	Buf Pav Co	"	1622	30	5407	15689	2 90	"	Medium	Fair Edges Chipped
	June	Milburn	Broadway	N Y C R R	"	"	1686	28	5245	14525	2 76	"	Light	Good
	May	Penfield	Niagara	West Ave	"	"	487	26	1409	4286	3 04	Franklin	Light	Generally Fair A few longitudinal cracks
	Sept	Peterson	Fillmore	Mills	"	"	775	26	2239	6802	3 03	Syracuse	Light	Good
	July	Shepard	Broadway	W S R R	PBM Naughton		1444	24	3850	11185	2 90		Medium	Good Joints open along center
1894	Oct	Koos Al	Broadway	William	O T Dutro		1310	19 1/2	2838	7935	2 79	Mack Blk	Medium	Fair Some soft brick A few longitudinal cracks Some depression
1895	Sept.	Bank Al	Court	South End	Buf Pav Co	Cement Jts	323	10 11	382	1072	2 80	Franklin	Light	Good
	May	Central	William	Lovejoy	D J Nugent	Drain Tile Cement Jts	1764	28	5488	14763	2 69	Mack Blk	Light	Good
	July	Douglass	Ellicott	Center	O T Dutro		462	32	1477	3379	2 28	Mack	Medium	Good
95-96		Laurel	Main	Michigan	Private L Gipp	No Drain Tile Cement Jts						Johnsonburg	No Traffic	Good Not open to traffic A few longitudinal cracks
1896	June	Alcarna	Elk	Sandusky	[illegible]	Drain Tile Cement Jts	1127	30	8707	8939	2 37	Mack	Medium	Good
	July	Schiller	Queen	Vanderbilt	G W Burke	Cement Jts	2676	30	8920	20990	2 36	Mack	Medium	Good
1897	Aug	Preston	Ferry	Auburn	PBM Naughton	Drain Tile Cement Jts	1073	30	3577	5998	1 67	McMahon Porter	Medium	
	Aug	Pooley Pl	Grant	Dewitt	L H Gipp	Drain Tile Cement Jts	1286	26	3715	8700	2.34	Franklin	Medium	
	Sept	Miller	Broadway	Walden	PBM Naughton	Drain Tile Cement Jts	2739	28	8528	19031	2.23	Mack	Medium	
	Oct	Pine	Broadway	Cypress	L H Gipp	Cement Jts	300	32	1068	2100	1.97	Porter Blk	Medium	

VARIOUS METHODS OF PAVING BRICK TESTS

Test	Authority	Method	Results
Lime Test	Nicholson Chase Baker	Immersed in Water: 3 days / 10 days / 5 to 10 days. Then Examined. Dried in Air 3 days	Should not split or spall Should not crack Should not crack
Specific Gravity		Formula $\frac{A}{I-W}$ Where A = wgt in air, I = wgt after absorption, W = wgt in water	Should range about from 2 to 2
Cross Breaking Test	Johnson	Brick laid edgewise on two supports. Distance between supports 7 inches. Loaded until breakage. Breaking load ÷ by width of brick. Gives Breaking Load per inch in width of surface as the brick stands when laid	Gives advantage to deeper brick which is so in actual practice
Transverse Test	Chase Baker	Formula $R=\frac{3wl}{2bd^2}$ or $W=\frac{2bd^2 R}{3l}$ Where R = modulus of Rupture, w = total wgt to break brick, l = length in inches, b = breadth, d = depth. Brick laid on knife edges 6 inches apart. More uniform results from testing Brick flat	Should be 1600 lbs or more per sq in when tested flat " " according to his sample No 6 truly first class Considers this Test equal in value to Absorption & Abrasion Tests
Crushing Test	Johnson	Applied on pieces [illegible] deep. Load Sustained ÷ by area in square inches of loaded surface. Gives Strength of Specimen in pounds per square inch	
	Nicholson	Applied on 2 inch cubes. Surfaces ground down to parallel planes	Should not be less than 14000 lbs per sq in on 2 inch cubes from any part of brick
	Baker	From Experiments on Soft Brick The strength of a 1/4 brick, 1/2, 3/4 and whole brick are to each other as 3 4 5. 6 respectively	Does not consider of much value since in actual practice the pressure with 1 1/2 inch tire is only about 1000 lbs per sq in loaded [illegible] 1/2 ton. Strength endwise is abt 1/3 to 2/3 strength flatwise, edgewise 3/4 "
Absorption	Baker	Specimens thoroughly dried out 6 weeks to 6 months. Weighed and Immersed in Water 24 hours. Dried and Weighed again	Sample No 6 truly first class product Absorption 1.5 %
	B P W Buffalo Chase Holman	Weighed and immersed in Water 48 hours	Buffalo: Ave. Absorption must not exceed 3 % Chase: Ave Absorption must not exceed 2 % Holman: Desired Absorption Limit 2 % for assurance of [illegible] being sufficiently compact
Abrasion	Johnson	Rattler steel lined 30" long 24" diam. Revolutions per min 40. 5 whole bricks to 5 cu. ft. granite 10 cast iron blocks 6 lbs ea Cushioning Material used	Average Loss of Brick divided by Average Loss of Granite Gives Comparative value
Abrasion	Baker	Rattler Wooden Staves Iron Heads 3-9 x 26" diam. Revolution per min 24. 546 pcs foundry shot or 1/2 lb Total 83 1/2. Time of Running 3 separate half hours	Sample No 6 truly first class " " as good in Abrasion as Quincy Granite
	B P W Buffalo N Y	Rattler Iron 3 long 2 diam. Revolutions per min 30 to 35. 1st Tumbling 100 lbs scrap iron and abt 100 lbs pig iron 6 to 16 lbs. With abt 7 different Brick. 2nd Tumbling 100 lbs scrap iron with Brick. Time of Running 1 hour each tumbling	Best Brick tested as well as ordinary Paving Sandstone Maximum Abrasion Per Cent should not exceed 30 %
	Holman Orton and Harrington	Rattler varying in size. 1st Max Loss obtained by filling bbl 15 % of vol. 2nd Per Cent Loss independent of Length of Barrel with such condition. 3rd Per Cent Loss increases more rapid rate than speed from 20 to 40 revolutions. 4th Per Cent Loss decreases with equal successive intervals of time up to 60 min tumbling	Recommended Speed 30 Revolutions per minute Duration 40 minutes The Use of Cast Iron Block in Rattler deprecated because of great Variability & Severity of Result upon the Brick
	Wheeler	Formula for Rating of Average Paving Brick $V = 5(18 - R) + 2(7 - A) + \frac{T}{220} + \frac{C}{1000} + \frac{10}{3^{25} - D} + \frac{10}{7^5 - H}$ The Mean of a large number of tests gave $R = 8^{00}$ per cent, $A = 2.^{00}$ per cent, $T = 2200$ pounds, $C = 10000$, $D = 2^{25}$, $H = 6^5$ Thus making $V = 100$ and Rattler test most important	V = an arbitrary comparative rating R = rattler loss in per cent of wgt of brick A = absorption " of wgt of brick C = crushing strength per sq in T = modulus of rupture " " D = specific gravity H = hardness by Mohs mineralogical scale Very good brick should exceed this value

Small depressions showed along the center of the street after it was cemented; when taken out the sand was found to have been washed out by the rain. It does not seem possible to use sand with broken stone without losing all of the sand filling. In the matter of the

rumbling noise, it has been general in the West. There are cases where the pavement, laid in cold weather and afterward cemented at a low temperature, has expanded a certain amount, probably due to the expansion of the brick and cement. If the brick were laid in very warm weather and thoroughly wet in cementing, they would be cooled down to the temperature of the water with which they were flushed, and the brick and cement would afterward expand from the temperature of the water to that of the air. Pavements may be laid in a temperature of 80 or 90 degrees, but the brick would be at a temperature considerably below 50. Raising the temperature above 100 would be sufficient to account for considerable expansion.

Mr. March.—If a broken stone base is used I think it is important that some filling other than cement should be used. In reference to the 2-inch sand cushion, in Buffalo, where it is customary to lay concrete for asphalt topping, the top has been left rough in order to get a better bond for the topping, and this has expanded so much it is necessary to leave a joint in the concrete when laying the pavement, and in that case, where the top of the concrete is rough, the cushion could be increased; that is, a thicker cushion would be advisable in order to compensate for the inequalities of the concrete and brick. If the sand is pushed aside the brick would rest on the stone, so, in case of a rough top, it strikes me a 2-inch cushion would be advisable; if the surface is smooth it is not so necessary, and possibly a 1-inch cushion would do.

Mr. Ricker.—There is a special claim made for brick made of certain chemicals. Do you know anything about this?

Mr. March.—I saw reference made to them in some magazine within the last week. They are composed of coal ashes and chemicals, and require no burning. They are ready for use in five hours after being made.

Mr. Mann.—Put in the presses and molded?

Mr. March.—I suppose so.

Mr. Green.—Slag brick are used in Toronto. Simply for a toothing along car tracks, laid in 2-inch sections.

Mr. Norton.—Another point to be considered is in the laying of the brick across the street and making the joints tight. If too tight, in rolling it will make an arch across the street, and no kind of filling will prevent that trouble.

Mr. Mann.—If brick and stone of the same size are laid on the same bed, the brick will produce more noise than the stone because of its metallic ring. Is this not so?

Mr. March.—Yes. Every pavement has its defects just as

anything else. The question is, which has the least at the least expense?

Mr. Ricker.—In case of brick between the rails of car tracks, do you know whether the expansion is sufficiently distributed to the gauge?

Mr. March.—I do not know.

Mr. Ricker.—What I had in mind is, it is sometimes necessary to pave between the tracks and outside of the rails, leaving parts of the street unpaved. What would be the effect?

Mr. March.—The effect of expansion. Expansion makes the brick rise.

Mr. Ricker.—Another trouble would be, a roll forms on both sides where there are hollow spaces under the girder rails.

Mr. Mann.—There is only a little space where the rails are bolted together.

Mr. Ricker.—Of course they have to have room for the joints.

Mr. March.—I do not think it would be a serious defect.

Mr. Norton.—The trouble has been that the pavement expanded over long blocks of the pavement rather than in the narrow gutter.

Mr. March.—It seems, however, to occur only in a very small area, about three feet square, as on Oakdale place. Most of the trouble of any amount is in a small area.

Mr. Ricker.—Are the brick laid closer at the ends than at the sides?

Mr. March.—The sides are not supposed to lay as closely as on the ends. If any filling is placed between them it is liable to cause transverse cracking across the street; any expansion, of course, would be noticeable there. On McDonough street, Brooklyn, the brick arched up that way, I believe, and though an attempt was made to roll it down with a 15-ton roller it was without effect. They took out a line of brick along the curb, but it had no effect. It was a regular brick arch.

Mr. Mann.—If the cracks are shown transversely across the street, then the expansion is transverse.

Mr. March.—That is probably true. It probably has no defects at all on its surface, caused by the ends of the brick being laid closer than the sides.

Mr. Norton.—It is the tendency of the men laying the brick to lay them in this manner. Probably the filling between the brick has driven them up. Closing the joints at the ends with broken brick makes the joint across the street very much closer.

Mr. March.—Care ought to be exercised in the selection of the

COMPARATIVE CONSTRUCTION AND COST OF BRICK PAVEMENTS IN VARIOUS CITIES

No.	City	Miles Dec 31 1896: Asphalt	Stone	Brick	Brick Course: Filling of Joints	Top	Bottom	Cushion	Foundation Course	Is Drain Tile used back of Curb?	Kinds of Brick used	Cost: Brick per M delivered	Curbing per lin. ft. in place	Per Sq. Yd. Complete	Results	Curbing Minimum Dimension: Thickness	Depth	Length
1	Akron Ohio		3	43	Formerly tar, Pitch and Cement and Tar			Sand 2"	Concrete, Furnace Slag at 4" per sq yd	No	Akron & Canton			$1.?? not including Curb		6	18	30 to 42
2	Albany NY	[illegible]	[illegible]	[illegible]	Portland Cement & Tar used [illegible]	One Course on edge as close as possible	None	Screened Coarse sand [illegible]	1 2 4 Concrete 6" [illegible]	-	Canton State, Catskill	$25 to $26	45 to 75¢ Granite	[illegible]	Quite satisfactory so far	5, 6"	15, 18"	42" Bluestone & Granite
3	Binghamton NY	3.0		0.7	Sand	One Course on edge, laid close	-	Sand 1"	6"	-	Corning	$14	60¢ Bluestone	$2.01	Unsatisfactory	4	30	20 to 48 Varying
4	Bloomington Ill			20	-	-	One course flat, Part with [illegible]	-	4" unlimited [illegible] sand	-	Bloomington & Springfield	$8 to $9	40¢ Sandstone	[illegible]	Very satisfactory	4	24	Not less than 36
5	Boston Mass	[illegible]	[illegible]	[illegible]	Have laid no Brick Paving in five years except one street [illegible] in 1894								$1.00 Granite			7	22 Granite	70"
6	Brooklyn NY	[illegible]	135	[illegible]	Portland Cement 1 1	One Course on edge laid close	None	Sand 1½"	1 2 4 [illegible] Cement Concrete 5" to 6" thick	-	Mack, Canton Block 3 × 4 × 9"	$20 to $22	65¢ to 75¢	$2.65	Fair	5	19"	42 to 90
7	Buffalo NY	[illegible]	[illegible]	[illegible]	[illegible] with Pure Cement [illegible]			Sand 1"	1 2 5 Concrete 6" thick	Yes 30" below top of curb	Syracuse, Franklin, Porter, Mack	[illegible]	[illegible] 45¢ [illegible] Sandstone	Formerly $2.75, Now $2.35	Fair to Satisfactory	4	[illegible]	[illegible]
8	Burlington Iowa							3"			Vitrified	$10	40¢	$1.?? [illegible]	Fair	[illegible]	30"	
9	Canton Ohio		1"	13	Formerly pitch, Now Cement			Sand 2"	Crushed Limestone 8"	No	Canton 3½ × 4 × 8	[illegible]	35¢ [illegible] Sandstone	Formerly $1.83, Now [illegible]	Quite good	6	20 to 24	[illegible]
10	Cedar Rapids Iowa			[illegible]	Sand	-	[illegible]	Sand 2	Macadam 6"	-	Galesburg & Des Moines	[illegible]	[illegible] Cement 36¢	[illegible] Curb	[illegible]	5	25	45
11	Charleston W Va			16"	-	-	None	Sand 2½	Sand 3, Tarred Boards 2"	-	Poste, Nemaha, Carey and others	$9.00	55¢ Sandstone	$1.72 Curb [illegible]	Satisfactory	6	24	36
12	Cincinnati Ohio	[illegible]	[illegible]	35	Coal tar pitch			Sand 2"	1 2 3 Concrete 6" thick	Yes 30" below top of curb	[illegible]	[illegible]	[illegible] Granite	$2.00 [illegible]	Fair to Satisfactory	5	21	60" to 84"
13	Cleveland Ohio	[illegible]	[illegible]	[illegible]	Asphalt & Cement	[illegible]		None	Sand	No	[illegible]	[illegible]	[illegible] 45¢ [illegible]	[illegible]	Generally fair	5	20	45 to 65
14	Clinton Iowa			[illegible]	Sand	One Course on edge, laid close	-	Sand 2"	Rubble and [illegible] sand 6"	No	[illegible]	About [illegible]	50¢ & 67¢ [illegible] Sandstone	[illegible]	Satisfactory	4"	12	36"
15	Columbus Ohio				Pitch	-	-		Broken Stone 8		All kinds Made in Ohio	[illegible]	[illegible] 35	Formerly $2.06, $2.01, Now [illegible]	Bad to Satisfactory	5	16	[illegible]
16	Davenport Iowa			11"	Sand		-	-	[illegible] Concrete 3	[illegible]	Galesburg [illegible]	[illegible]	30¢ to 43¢ [illegible] Sandstone	[illegible]	Fair to Satisfactory	5	18, 20	36"
17	[illegible] Ohio	[illegible]	[illegible]	[illegible]	[illegible] Portland Cement				[illegible] Concrete 6	-	[illegible]	[illegible]	[illegible]	[illegible]	Good	5"	18	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	Pitch	-	-		[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 30¢, [illegible] 25¢	Formerly $2.00, Now $2.00	Fair to Satisfactory	3	16	48
19	Dubuque Iowa		[illegible] 70	3.75	Sand	One Course	None	Sand 1½"	6 Concrete & Macadam Grout	No	Galesburg, Des Moines, Lehigh	$10 to $12	30¢ to 35¢ Limestone	[illegible] Not including Curb	Fair to Satisfactory	6"	18	36
20	Dunkirk NY		3	3.5	Portland Grout	One Course set on edge laid close	-	1"	Broken stone [illegible] 1 2 3 [illegible] Concrete 6"	No [illegible]	Brady's Run, Pure		30¢ to 35¢ [illegible] Sandstone	$1.70, $1.68	Excellent	5	8	36"
21	Easton Pa			[illegible]	Pitch and sand	-	-	1"	1 2 4 Concrete 6"	No	[illegible]	$7 to $8	Limestone 65¢, [illegible] Bluestone 55¢	Formerly $3.05, Now $2.?? Exc. of curb	Satisfactory	4	20	
22	Evansville Ind			20	Sand	-	-	-	Concrete 6"		Evansville, Porter, Hallwood, Trenton, [illegible]	Evansville $11, Porter etc $14	47¢	$2.05	Fair	5	22	40
23	Galesburg Ill			13	-	-	One course laid flat, part with 3" [illegible] sand	1½"		No	Galesburg	Formerly [illegible], Now $9.50	25¢ [illegible]	Formerly $1.40, Now $1.??	Satisfactory	5"	20	30 to 60"
24	Hartford Conn			0.11	Pitch	-	None	1"	Macadam rolled hard	-	Hallwood	$14.25	85¢ Granite		Fair to Satisfactory	5	24	48 to 54
25	Indianapolis Ind	33		7	Cement & [illegible]	-	-	2"	1 2 4 Concrete 6" thick	-	[illegible] Brazil Blue [illegible]	$15 [illegible]	60¢ straight, 60¢ combined curb & gutter	$2.00	-	5	24	60
26	Kansas City Mo	[illegible]	1"	[illegible]	Sand, Cement grout or Asphalt	-	-	-	4" to 6" Macadam 6"	-	Pittsburg, Des Moines, Kansas City Vitrified	$9 to $12	45¢ Limestone	$1.?? to $1.?? Without curb	All good, [illegible]	5	24	40"
27	Kenosha Wis			1.5	Sand	-	-	1½	Macadam 6 thick	-	Galesburg Standard Repressed	$14 [illegible] Kenosha	[illegible] 42¢	$1.?? Exc of curb	Satisfactory	4	18	40
28	Lafayette Ind			18	-	-	One course common flat	-	6" Pit Gravel	-	Decatur, Bloomington, Fredericksburg, Clinton, Canton	$11 to $14	[illegible]	$1.?? Exc of Curb	The expect to do better, [illegible]	4, 5, 6"	20", [illegible]	48 to 120"
29	Lincoln Neb			13	-	-	One course laid flat	1"	Sand 6"	-	Lincoln	[illegible] $12	Colorado Sandstone [illegible] 75¢	$1.25	Fair to Satisfactory	4"	20"	36
30	Lockport NY	1		2.4	Portland Sand & Murphy Grout Filler	-	None	2"	1 2.5 Concrete 6" thick	-	Porter, Mack, U S, Canton, Pure		[illegible] 40¢	[illegible] $2.?? to $1.?? [illegible]		4	16"	30
31	Louisville Ky	[illegible]	[illegible]	[illegible]	Pitch	-	-	-	1 2 5½ 7 Concrete 6"	-	[illegible]		Limestone 65¢	[illegible]	[illegible]	6	22"	60"
32	Memphis Tenn	[illegible]	10	5	[illegible] pitch with [illegible] Asphalt	-	-	1½	1 2 3 Concrete 7" thick	-	[illegible]	[illegible]	Georgia Granite 42½¢	Formerly $3.10, Now $2.??		6"	20	48
33	Minneapolis Minn	10	10	1	Asp Cement, Murphy Grout	-	-	1"	1 2 5 Concrete 6" thick	-	Des Moines, Galesburg, Purington, Streator	$14 to $18	Granite 73¢	$1.?? Exc of Curb	Not in use long enough	6"	20	48 [illegible]
34	Newark NJ	[illegible]	[illegible]	[illegible]	Gran Grout, Sand, Pitch	-	-	Sand 2"	-	-	[illegible]		Bluestone [illegible] set in Concrete	[illegible]	Satisfactory	4	20"	36
35	Niagara Falls NY	1.6		2"	Formerly Port Cement, [illegible]	-	-	Formerly Sand, [illegible] 1"	1 5 10 Port Cement Concrete 6" thick	Yes 28" below top of curb	Mack, Park, [illegible]	$14 to $18	[illegible] 60¢	Formerly $2.40, [illegible] $2.02, Now $2.25	Good, [illegible]	Formerly 6", Now 5" [illegible]	Formerly 22, Now 20	36
36	Omaha Neb	[illegible]	[illegible]	10.7	Sand	One Course only set on edge		5"	1 2 5 Concrete 6	No	Galesburg, Des Moines, Kansas City, Nebraska	$14	[illegible] 35¢ [illegible]	$1.?? [illegible] Without Curb	Poor to Fair	5"	20"	30"
37	Peoria Ill	[illegible]	[illegible]	[illegible]	Sand, [illegible] Port Cem grout [illegible]	-	-	Sand 1 to 2"	1 5 6 Port Cement Concrete 6"	No	[illegible]	$11 to $18	[illegible]	[illegible]	Satisfactory	5", Now 6"	20, 36"	40", 48"
38	Providence R.I.	[illegible]	[illegible]	[illegible]	Port Cement	One Course set on edge laid close	None	Sand 1"	1 2 4 Concrete 6" thick	No		[illegible]	Granite 75¢	[illegible]	Good [illegible]	7"	15"	60"
39	Rochester NY	[illegible]	[illegible]	[illegible]	Pitch	-	-	-	-	Yes	Canton [illegible]		50¢	[illegible]	Good	8	16"	36
40	Rockford Ill			[illegible]	Sand		One Course laid flat [illegible]	[illegible]	[illegible]	No	Galesburg	[illegible]	Sandstone 65¢	[illegible]	Satisfactory	5	24"	45
41	Rock Island Ill		5	5		Flat	Sand 2"	5"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Satisfactory [illegible]	6"	[illegible]	36
42	St Joseph Mo	[illegible]	[illegible]	[illegible]	Sand		One Course laid flat [illegible]	1"	[illegible]	No	[illegible]	$10"	[illegible]	$2.??	[illegible]	5"	24"	30 to 60"
43	St Louis Mo	[illegible]	[illegible]	[illegible]	[illegible] Port Cement	One Course set on edge	None	1"	Concrete 6" thick	-	[illegible]	$13"	[illegible]	$2.??	Satisfactory	6"	16	36"
44	Scranton Pa	[illegible]	[illegible]	[illegible]	Cement [illegible] Pitch	One Course set on edge laid close	-	2"	1 2 7 Concrete 5" thick	-	Scranton, Mack	[illegible]	[illegible]	[illegible]	Satisfactory	4"	24	36" to 60"
45	Springfield Ill				Sand	One Course on edge	-	1½	1 2½ 4 Concrete [illegible]		Springfield	[illegible]	[illegible]	[illegible]	Very	4"	20	30
46	Syracuse NY	11	5	11	Port Cement [illegible]	-	-	½	1 2 5 [illegible] Concrete 6"	Yes [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Fair	5"	15"	48
47	Terre Haute Ind	[illegible]	[illegible]	[illegible]	1 1 Cement	One Course set on edge laid close	-	1"	2 3 6 Concrete 5" thick	[illegible]	Canton [illegible]	[illegible]	[illegible]	[illegible]	Unfavorable [illegible]	4	15"	36 to 54
48	N. Tonawanda & Tonawanda NY			[illegible]	Formerly sand	-	-	1½	[illegible] 6 Concrete	[illegible]	Canton, Porter, [illegible]	[illegible]	[illegible] 35¢	[illegible]	Satisfactory	4	15"	36"
49	Toronto Ont	16	[illegible]	[illegible]	1 1 Grout [illegible] Pitch	-	-	1 to 1½	1 3 6 Port Concrete 6 to 6	-	[illegible]	[illegible]	[illegible]	[illegible]	Fair to Satisfactory	4	20	45
50	Trenton NJ	[illegible]	[illegible]	[illegible]	[illegible]	-	-	2"	[illegible]	No	Trenton [illegible]	[illegible]	30¢ to 35¢	[illegible]	Very Good	4"	16	36"
51	Troy NY	[illegible]	[illegible]	[illegible]	[illegible] Pitch [illegible]	-	-	1½	1 2 5 Concrete 6 thick	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Fair to Satisfactory	3	24	48
52	Washington DC	[illegible]	[illegible]	[illegible]	Only a [illegible] amount on Streets, [illegible] used on Alleys			[illegible]	1 2 6 Concrete 4 thick	No	[illegible]	[illegible]	[illegible]	[illegible]		8, 6"	8, 20	[illegible]
53	Youngstown Ohio	4	1	3	1 1 Cement	One Course on edge laid close		1"	1 3 6 Port Cement Concrete 4 & 6 thick	Only in [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Fair to Satisfactory	6"	18	30
54	Wilmington Del	[illegible]	[illegible]	[illegible]	Sand, [illegible] Cement	-	-	[illegible]	2 [illegible] & 5	No	[illegible]	[illegible]	[illegible]	[illegible]	Fair	5	16"	[illegible]
55	Philadelphia Pa	[illegible]	[illegible]	[illegible]	Cement			1"	Concrete 6 thick	-	[illegible]	[illegible]	[illegible]	[illegible]	Satisfactory	6	22"	72"

cement for joint filling and foundation. In the Franklin street pavement we used Royal Crown Belgium Cement in front of the City Hall. The brick of the Franklin street pavement has been generally good. There are one or two places that are bad.

Mr. Norton.—It shows a rumbling in one or two places.

Mr. Mann.—Maybe Mr. Vander Hoeck can tell us something about the pavements in Holland?

Mr. Vander Hoeck.—There are several miles of highways paved with brick in Holland. I am sorry to say they are in very bad condition. They were laid years and years ago. There was no attempt made to get a good foundation, and the bricks were simply laid in sand; consequently the pavement is full of holes, and very expensive to keep up.

Mr. Vander Hoeck.—I do not know exactly where the trouble is, but I thinks it is in the foundation; and in some places the mud will come out between the brick. As far as the brick is concerned, I do not think it will be very easy for the makers to make brick conforming to a certain standard to last 200 or 300 years.

Mr. Mann.—I went into an old mission in Ahualulco, Mexico. In front of the altar were the distinct marks of the knees and toes of the worshipers worn out in the brick. In the doorway it was worn down to not more than one inch in depth. The brick were set on edge. They were regular sun-dried brick.

ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
BOSTON
CLEVELAND
Philadelphia
PACIFIC COAST
ST. LOUIS
CINCINNATI
LOUISIANA
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC OCEAN
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND
OHIO
KY.
W.VA.
VA.
MD.
DEL.
ME.
MASS.
ARIZ.
N. MEX.
OKLA.
IND. TY.
ARK.
TENN.
N.C.
S.C.
MISS.
ALA.
GA.
TEX.
LA.
FLA.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. SEPTEMBER, 1899. NO. 3.

COVERED RESERVOIRS.

BY FRANK L. FULLER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 17, 1899.*]

FRANKLIN, N. H., RESERVOIR.

IN 1889 the writer designed a covered masonry reservoir in connection with a system of water supply for the town of Winchendon, Mass. The system was not built at that time, but the same reservoir design was used in 1891 in connection with a water works system for the town of Franklin, N. H.

A section of that reservoir and also a cut from a photograph are given. The brick piers supporting the roof are 12 x 12 inches, laid in Portland cement. The roof is of hard bricks laid in Rosendale cement and 8 inches in thickness.

The average load at the base of each pier is a little less than 23 tons per square foot.

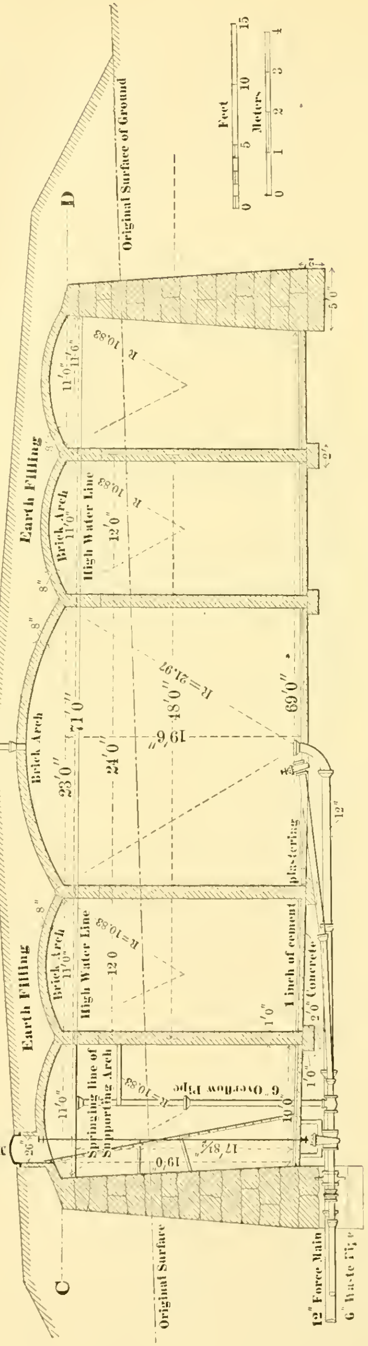
As the Winchendon reservoir is similar in construction, the detailed description of that reservoir given further on, will answer for this, and also largely for the Methuen reservoir.

The Franklin reservoir was the second covered reservoir built in New England, and the first circular one.

A copy of the final estimate for its construction, which was by contract, will give its cost in detail:

* Manuscript received August 30, 1899.—Secretary, Ass'n of Eng. Socs.

Capacity to High Water Line=504,300 Gallons.

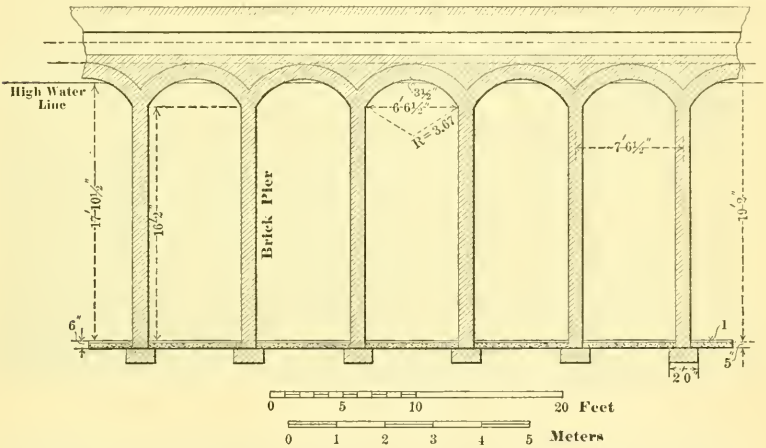


Circular Covered Masonry Reservoir at Franklin, N. H., Water Works.

2882.4	cubic yards	earth excavation	@ $0.40	$1,152.96
714.8	" "	local rubble masonry in Am. cement	@ 6.80	4,860.64
18.6	" "	Portland cement brickwork	@ 16.96	315.46
120.8	" "	American " "	@ 13.96	1,686.37
57.5	" "	" " concrete	@ 6.75	388.12
410.8	square "	1-inch Portland finishing coat on bottom	@ 45	184.68
464.4	" "	½-in. Portland plaster coat on sides	@ .40	185.76
52.5	lineal feet	12-inch cast iron pipe laying	@ .50	26.25
73.9	" "	6 " " " " "	@ .35	25.87
Extra		for 40 barrels Portland cement on bottom	@ 1.80	72.00
"		" 2 " " " used around pipes and gates	@ 3.48	6.80
"		not included above		127.45
				$9,032.36

METHUEN RESERVOIR.

In 1893 a covered masonry reservoir of a capacity of 1,013,000 gallons was built by the town of Methuen from plans by the writer. It is similar in design to the Franklin reservoir, but has an inside diameter of 95 feet at the top and 93 at the bottom. The piers are



SECTION OF OUTER RING OF PIERS AND SUPPORTING ARCHES F.—F.

The Inner Ring of Piers is the same except that the piers are 2 inches longer.

also larger and the reservoir deeper. It is practically an enlargement of the Franklin reservoir by the addition of another circular covering arch of the same span and rise.

The roof is supported by 60 brick piers 16 inches square, laid in Portland cement.

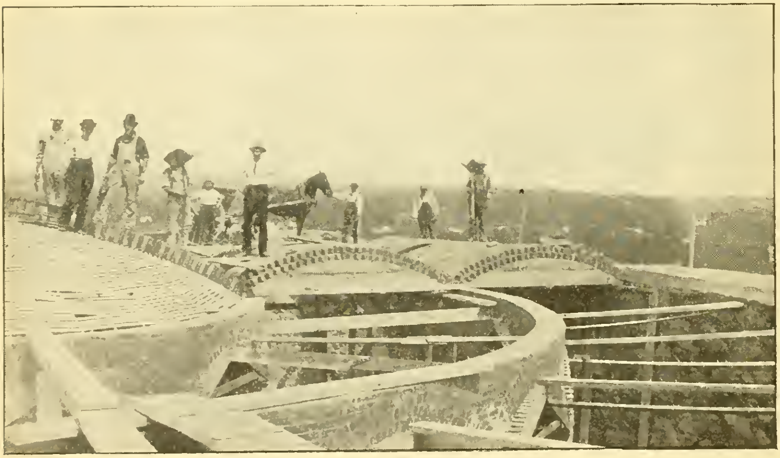
The dome and covering arches are of brick, 8 inches in thickness, laid in Rosendale cement. The average load per square foot at the base of each pier is about 14.1 tons. This includes a possible load of 50 pounds per square foot for snow and ice in the winter.

The earth covering over the roof has a slope of about 1 in 38. The embankment about the masonry wall where it is above the original surface of the ground has a slope of 1 in 2.

The height of the middle row of piers from the bottom of the reservoir to the springing line of the lintel arches is 18.25 feet. The piers are 7.54 feet apart on centers, measured along the circumferences of their respective circles.

When full, there is a depth of 19.7 feet of water in the reservoir.

All materials were furnished by the town of Methuen, and delivered at the reservoir site. All work was done by day labor, except in laying the rubble masonry wall. This was furnished by Mr. Wm. S. Marsh, of Lawrence, at $1.64 per cubic yard. The wall contained 1084 cubic yards. Mr. Marsh also put the plaster coat on



the inside of the masonry wall for the sum of 23 cents per square yard. This coat was composed of equal parts of Portland cement and sand.

The total cost of the reservoir, exclusive of land, was $16,-864.64.

HARVARD RESERVOIR.

In 1895 the writer made plans from which was built a small covered reservoir for use in connection with the water supply for the residence of Fiske Warren, Esq., at Harvard, Mass.

The reservoir is 22 feet in diameter at both top and bottom, and 13.5 deep. The walls are of local rubble stone, partly obtained at the reservoir site. The reservoir contains, when at high water level, 12 feet of water, or 34,100 gallons.

The roof is a circular dome 22 feet span and 3.5 feet rise. It is composed of brick laid in American cement, and is 8 inches in thickness.

The bottom consists of 6 inches of concrete.

The writer is unable to give the cost.

WINCHENDON RESERVOIR.

Bids for this reservoir were received November 25, 1895. It was built from plans made in 1889, and, as before explained, used in 1891 in building the Franklin reservoir. The only change made was to increase the size of the piers from 12 x 12 to 12 x 16 inches.

Like the others, the water to be stored in this reservoir was from an underground source. Hence it was decided to use a covered reservoir.

As built, the reservoir has an internal diameter of 69 feet at the bottom and 71 feet at the top. The depth of water is 17 feet 8 inches. The local rubble masonry wall is 5 feet thick at the bottom and 2½ feet at the top, and has a total height of 21 feet, 2 feet of this amount being below the bottom of the reservoir. The capacity to high water line, or the top of the overflow pipe, is about 504,000 gallons.

Two sets of brick piers, laid in Germania Portland cement mortar, 12 x 16 inches, connected by lintel arches, support two rings of brickwork, which in turn support the concrete dome at the center and two circular concrete covering arches. The brick rings are 12 inches, and the concrete roof is 8 inches in thickness. An embankment surrounds that part of the masonry wall which is above the original surface of the ground, and the filling is extended over the roof and properly graded and seeded to grass.

Test pits were sunk at the reservoir site in order to ascertain the location and depth of the ledge, which was known to exist. It was found impossible to entirely avoid the ledge, and considerable rock excavation was required at the bottom on the westerly side.

The rubble masonry wall was begun in April, 1896. The core was left until the wall had been built, when it was removed and placed in layers and wet and rammed about the back of the wall. The wall was built of local rubble stone, and considerable difficulty was experienced in obtaining it of suitable quality. The ledges in the vicinity were found to be unfit, and the wall is largely composed of split field boulders.

At the top of the wall a skewback was cut, from which to start the outer concrete covering arch. A derrick and hoisting engine were used in making the excavation and laying the wall.

The ledge was excavated to a sufficient depth to allow 6 inches of concrete being placed on the bottom. The ledge was more or less disintegrated, and but little of that removed was fit for use in the wall.

All piers rest on solid ledge, or on large granite blocks firmly bedded in the bottom.

The piers are laid in Germania Portland cement mortar, the lintel arches connecting them and the spandrel filling between them being of American cement brickwork 12 inches thick.

The covering arches and dome at the center are of Portland cement concrete 8 inches in thickness. The cement used was of the Germania brand, and the proportions were 1 of cement, 2 of sand and 5 of broken stone, not over 2 inches in its longest dimension. Centering for the entire roof was put in place before any concrete was used.

Before the covering arches or dome were started the embankment about the masonry wall was raised to the top of the wall and thoroughly rammed, thus assisting the wall to resist the thrust of the arches.

The concrete was put in place in sections bounded by radial lines. The positions of these sections of covering arches and dome were such that they were on radial lines extending entirely across the reservoir from circumference to circumference, thus tending to transmit any horizontal thrust to the rubble masonry wall.

The concrete was prepared by a gang of five or six men, who put it in place as soon as it was thoroughly mixed. The amount prepared at one time was one barrel of cement with the proper amount of sand and broken stone.

Enough water was encountered in the excavation for wetting the bank and for use in making mortar and concrete.

The work of putting the concrete in place began July 14 and ended July 28.

About 100 cubic yards of concrete were used in the roof, and a saving of about $700 was made by using concrete instead of brick.

After the last concrete had been in place fourteen days the wooden centering was removed and the roof found to be hard and smooth, and no cracks or settlements could be detected. As the water in the reservoir is above the freezing point, and as there is a covering of from 2 to 3 feet of earth over the top, there can be no action of the frost upon the concrete, and it should last indefinitely.

At the center is a ventilator consisting of an 8-inch cast iron sphere perforated with $\frac{1}{4}$-inch holes.

Entrance to the reservoir is had through a 26-inch manhole in the roof, on the top of which is placed a heavy cast iron cover secured by a padlock.

The soil on the top and sides of the reservoir was seeded to grass to protect the bank from being washed by the rains.

A 6-inch vertical overflow pipe connected with a waste pipe of the same size prevents the reservoir being overflowed. The top of this pipe determines the high water level of the reservoir.

Water can be withdrawn from the reservoir by the 14-inch main only to within 6 inches of the bottom at the center. All below that level must be drawn out through the 6-inch waste pipe, which can be done by opening a 6-inch gate in the bottom of the reservoir. This arrangement prevents any sediment from entering the distribution system. The 6-inch waste pipe passes through the bottom of the reservoir with a slight inclination and comes to the natural surface of the ground a few hundred feet below the reservoir.

On account of the large amount of ground water in the soil at the reservoir location a hole was made in the 6-inch cast iron waste pipe, so that it acts as a drain for reducing the level of the ground water under the reservoir and prevents any upward pressure on the bottom when the reservoir has been emptied. There is also a 2-inch composition pipe set vertically in the concrete bottom, making direct connection between the space under the concrete bottom and the reservoir. This pipe is about 1 foot long, and at the top has an elbow and on it a check valve opening toward the reservoir. In case the water in the reservoir is drawn lower than the outside ground water this check valve will open and the ground water flow into the reservoir, so that no pressure can be exerted on the concrete bottom.

An underdrain composed partly of 4-inch Akron pipe, laid with open joints and partly of broken stone, is laid on the inside of the masonry wall and just below the under side of the concrete bottom. This collects the ground water and brings it near the point where the 6-inch cast iron waste pipe passes through the wall.

The sides and bottom received carefully applied plaster and brush coats of Portland cement, and the reservoir is practically watertight.

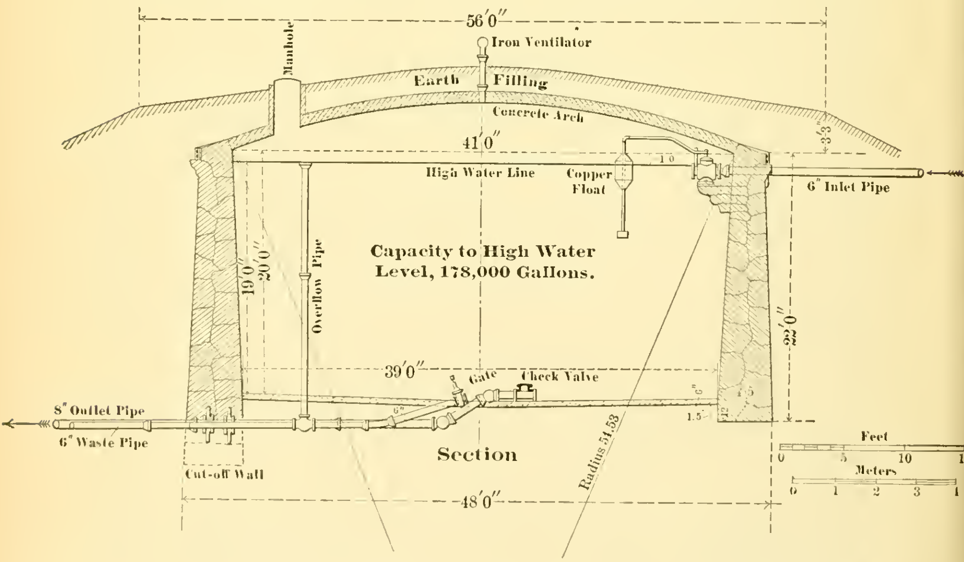
The cost of the reservoir is shown in detail by a copy of the final estimate of the contractor, Mr. Thomas Hennessey, Holden, Mass.:

3472.6 cubic yards of earth excavation	@	$0.55	$1,909.93
352.0 " " rock "	@	1.50	528.00
643.5 " " local rubble masonry	@	4.50	2,895.75
69.0 " " Fitzwilliam rubble masonry	@	5.50	379.50
3.4 " " Fitzwilliam rubble pier foundations	@	16.00	54.40
316.9 lineal feet of 14-in. pipe laying	@	.25	79.23
285.2 " " " 6 " " "	@	.25	71.30
27.7 cubic yards Portland cement brickwork	@	18.88	498.60
16.6 " " American " "	@	18.88	498.60
81.1 " " American cement concrete on bottom	@	5.00	405.50
98.8 " " Portland cement concrete on roof	@	8.00	790.40
464.2 square " Portland cement plaster coat cn sides	@	.25	116.05
411.0 " " Portland cement finishing coat on bottom	@	.25	102.75
217.0 lineal feet of drain in bottom	@	.12	26.04
204.0 cubic yards of borrowed earth	@	.55	112.20
			$8,218.65

Had there been no ledge in the bottom the cost would have been reduced $446.60, making the total expense $7772.05.

RESERVOIR FOR THE MASSACHUSETTS HOSPITAL FOR EPILEPTICS, MONSON, MASS.

This reservoir is a circular masonry structure covered with a dome or roof of concrete. It is 39 feet in diameter at the bottom



Circular Distributing Reservoir, at Monson, Mass., for Massachusetts Hospital for Epileptics.

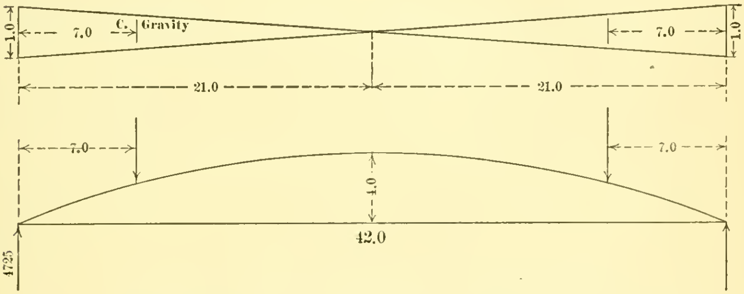
and 41 at the springing line of the roof, 20 feet above the bottom. High water level is at elevation 659.77 above sea level, and 1 foot below the springing line of the roof.

When full the water is 19 feet in depth, and the reservoir contains 178,000 gallons.

It is located about 2800 feet southwest of the hospital buildings. The elevation of the natural surface of the ground at the center was 656.2. Before making the final location a number of test pits were dug in order to decide where the least rock would be encountered. At the point selected, the ledge was 7 feet below the surface at the center, and at the bottom the entire excavation was in rock.

The excavation made was 3 feet greater in diameter than the outside diameter of the reservoir, or 51 feet. The bottom of the wall, except at the point where the 8-inch outflow and 6-inch waste pipe enter the reservoir, is at elevation 638.7. At the point mentioned the wall is several feet deeper, in order to properly surround these pipes.

The wall is 4.5 feet thick at the bottom and 2.5 at the top. It is built of rubble masonry laid in mortar composed of one part



Determination of Dimensions of Steel Band.

of Hoffman cement and two parts of good sand. A portion of the stone came from the excavation and a portion from a ledge opened by the contractor on the reservoir grounds. Some stone was also brought from the Flynt quarries.

When the rubble masonry wall had been carried to an elevation a little below high water level a band made of two plates of soft steel, each 12 inches in width by $\frac{1}{2}$ inch in thickness, was riveted together in place on blocking, so as to inclose the wall when completed. The band was 46 feet in inside diameter, and made of ten plates about 29 feet in length. The plates break joints and have a splice plate on each side. That on the continuous side is 24 x 12 inches by $\frac{1}{4}$ inch in thickness. That on the other side is of the same size, but $\frac{1}{2}$ inch in thickness. Each joint has twenty-six rivets $\frac{7}{8}$ inch in diameter. There is a rivet every 3 feet between the joints.

One coat of boiled oil was applied at the shop and two coats of red lead after the band was in place.

After the paint was dry the wall was completed inside of the band, and the band inclosed in masonry or concrete to protect it from rusting.

The band was furnished in place by Edward Kendall & Sons, Cambridge, for $248, they being the lowest bidders.

The object of the band is to resist any thrust caused by the action of the concrete roof.

The dimensions of the steel band were determined as follows: Two radial sections of the concrete roof were assumed as shown in diagram, the width of the wedge-shaped piece being 1 foot, as measured along the circumference of the masonry wall. The average weight of the concrete roof, including the earth covering, snow, etc., was assumed to be 450 pounds per square foot.

The load for this radial section would be $\frac{21 \times 450}{2} = 4725$ lbs.

The resultant acts at the center of gravity of the section, or 7 feet from the inside of the masonry wall. The moment about the point of support would be $4725 \times 7 = 33{,}075$ pounds.

This moment is equal to a horizontal moment consisting of the horizontal thrust on the section, multiplied by the rise of the roof, or $\frac{4725 \times 7}{4} = 8268$.

This pressure acts upon each section of the band 1 foot in length.

The circumferential stress on the steel band at any point would be $\frac{8268 \times 42}{2} = 173{,}628$ pounds.

Assuming 15,000 pounds per square inch as a safe stress to which to subject the steel band, the area of the cross-section would be $\frac{173628}{15000} = 11.57$ square inches.

The band used is 12 inches by 1 inch, with one $\frac{7}{8}$-inch rivet hole out, giving a net area of 11.12 square inches, which is nearly the area called for.

In making this computation the tensile strength of the concrete was disregarded.

The concrete dome or roof has a diameter of 41 feet and a rise of 4 feet.

According to the specifications, either Dyckerhoff, Germania or Alsen Portland cement was to be used. The W. N. Flynt Granite Company, who had the contract, decided to use the latter brand.

The concrete is 10 inches in thickness at the springing line, and decreases to 8 inches at the center. It was put in place on accurately and thoroughly built wooden centering, covering the entire reservoir. The centering was supported on large chestnut posts, which rested on a set of hardwood wedges, which were driven out when the centering was removed. The boarding of the center was of good quality planed spruce, tongued and grooved.

The concrete was composed of one part, by measure, of Alsen Portland cement, two and one-half parts of good sand and four and one-half parts of broken stone, not over 2 inches in its longest diameter.

The concrete was thoroughly mixed as dry as could be well rammed, and put in place as quickly as possible. The amount required for the roof was about 40 cubic yards.

The work was begun about 10 o'clock A.M. November 4, 1897, and completed at noon of the next day, or in twelve working hours.

As soon as the concrete had begun to set it was covered with 5 or 6 inches of earth to prevent freezing. Afterwards about 2 feet of soil was put on in the center, increasing to about 3 feet at the circumference. An embankment was also built about the part of the masonry wall above the natural surface of the ground.

On December 3, 1897, the wedges under a number of the posts supporting the centering were removed. There appeared to be no settlement of the concrete roof. On December 24 the entire centering was removed. The concrete roof appeared hard and smooth. No settlement occurred, and no cracks could be discovered.

The masonry wall was then carefully pointed up, and a $\frac{1}{2}$-inch plaster coat composed of equal parts of Alsen Portland cement and sand was put on. The object of the plaster coat was to make the reservoir as nearly watertight as possible. Later the wall was gone over with a brush coat of neat Portland cement in the form of a thin paste.

In building the masonry wall great care was taken to leave no voids and to have a wall of solid stone and mortar, preferably with as much stone and as little mortar as possible and still have all the joints filled. No stone was allowed to extend entirely through the wall, as this would form a continuous joint through the wall along which the water might escape.

At the point where the 8-inch outflow pipe and the 6-inch waste pipe enter the reservoir the wall is carried somewhat deeper, and is carefully built under and around the pipes. Cast iron flanged sleeves are secured to both pipes by a lead joint at the

center of the wall, to prevent the water following the outside of the pipe through the wall.

On the 6-inch waste pipe, nearly under the manhole, is a 6-inch T, in which is placed a 6-inch pipe with the upper end at high water level. On the inner end of the 6-inch waste pipe is a 6-inch gate. This gate is closed except when draining the lower part of the reservoir. The outer end of the waste pipe comes to the natural surface of the ground about 170 feet from the center of the reservoir.

Considerable ground water was found in the reservoir excavation. In order to relieve the bottom from an upward pressure when the reservoir is empty, the bottom of the excavation was underdrained by placing a layer of broken stone over the top of the ledge. By means of 4-inch Akron drain pipe the ground water is brought together under the concrete bottom and passes through the footing course of the masonry wall and out to the natural surface of the ground through a 4-inch cast iron pipe. Even in the dryest weather there will be some flow from this pipe, but it is in no sense due to leakage from the reservoir. It is the natural ground water which accumulates around and under the reservoir, and runs off through the drain.

Outside the reservoir is a 4-inch gate on the 4-inch cast iron drain pipe. By closing this gate the flow of the ground water from around and under the reservoir is checked, and it will rise to such a level outside of the reservoir wall that it will escape at some point.

If the reservoir is emptied when the outside water is above the level of the bottom, as before mentioned, there will be an upward pressure on the bottom, which will tend to push it in. As the area of the bottom is 1195 square feet, the total pressure would be considerable. If the outside water stood 4.6 feet higher than the bottom the upward pressure would be 2 pounds to each square inch, or a total upward pressure of 172 tons. The concrete bottom is 1 foot thick, and if the weight of the concrete is called 140 pounds per cubic foot it will by so much reduce the upward pressure of the ground water, and the net upward pressure would be about 88 tons.

It is probable that the ground water will stand at a higher level than that mentioned.

If the 4-inch gate is closed the ground water will form a water jacket to a certain height and lessen the tendency, if any, to leakage from the reservoir.

To relieve this upward pressure when the reservoir is empty and the 4-inch gate on the 4-inch cast iron drain pipe is closed two

2-inch composition pipes, with check valves similar to that mentioned in connection with the Winchendon reservoir, are provided.

The cost of the reservoir was $5644.08, as shown by the following copy of the W. N. Flynt Granite Company's final estimate. To this should be added the $248 paid for steel band:

820.0 cubic yards of earth excavation, in reservoir.....@	$0.50	$410.00
693.1 " " " rock " " " .....@	2.00	1,386.20
40.0 " " " earth " " pipe trench, within 15 feet of reservoir...@	.50	20.00
32.7 " " " rock excavation in pipe trench, within 15 feet of reservoir...@	2.00	65.40
426.1 " " " rubble masonry in Hoffman cement ....@	5.50	2,343.55
39.8 " " " Alsen Portland cement concrete, in roof ....@	12.50	497.50
3.2 " " " same, enclosing steel band, and in cut-off wall ....@		40.00
48.5 " " " " on bottom and around pipes..@	6.00	291.00
0.5 " " " American (Hoffman) cement brick masonry ....@	8.50	4.25
293.2 square " " Portland (Alsen) cement plastering on wall..................@	.35	102.62
835.3 cubic " " borrowed earth ....@	.35	292.36
39.0 lineal feet " 8-inch cast iron pipe laying........@	.80	31.20
60.0 " " " 6 " " " " " ....@	.80	48.00
47.7 cubic yards of broken stone about under drain and on bottom ....@	1.87	89.20
137.0 lineal feet of 4-inch cast iron pipe laying (under drain) ....@	.15	20.55
15.0 lineal feet of 4-inch Akron pipe, laid, for under drain ....@	.15	2.25
		$5,644.08

If there had been no rock excavation the cost would have been $4263.02, making a reduction of $1381.06.

From his experience and observation, the writer believes that concrete can be used with entire satisfaction as a covering for reservoirs, and at less cost than brick.

If the reservoir is circular the entire centering should be put in place before any concrete is used. If the covering is of brick it is often possible to remove the centers before the whole roof is completed and use them in building another section of roof.

LOCKS AND LOCK GATES FOR SHIP CANALS.

By Henry Goldmark, Member of the Detroit Engineering Society.

[Read before the Society, March 24, 1899.*]

The problems of canal construction as a part of the civil engineer's work have within recent years assumed new and unexpected prominence. Several important canals for a navigation of the first class have lately been completed, and further projects of unparalleled magnitude are now under construction or the subject of serious discussion.

Among the large works recently finished abroad may be mentioned the Manchester, the North Sea-Baltic and the Corinth canals and the enlargement of the canal prism at Suez and Amsterdam. In America the most important waterways under construction or survey are the great drainage canal at Chicago, now nearly finished; the rival projects at Panama and Nicaragua, and the equally important plan for a canal of the first class connecting the Great Lakes with tidewater.

All this activity is the more striking because for more than a generation the rapid development of railroads appeared to have given a death blow to new canal construction, and many existing canals had suffered a decrease in their traffic or had been entirely abandoned. There were, however, good reasons for this temporary decline, which was not due to any inherent weakness in canals as such, but rather to a mistaken public policy by which their great advantages were not properly made use of. The superior economy of transportation by water with vessels of proper design and in waterways of considerable size is not open to question. The modern freight steamer on the high seas and our own Great Lakes carries freight at a cost much less than even the lowest railroad rates. The tonnage of the lake traffic particularly has of late years advanced by leaps and bounds.

It is perhaps impossible to reach the same high degree of economy in the case of canal and river channels, which are necessarily more restricted. But in canals of large cross-section, using modern vessels propelled by power, the cost per ton mile should not be much greater than in open water. The real reason why our canals have decreased so much in relative importance lies in the fact that in size, in construction and especially in the nature of the

*Manuscript received April 14, 1899.—Secretary, Ass'n of Eng. Socs.

boats used on them, they are many years behind the times, and represent a phase of development long past in all other departments of transportation. When operated in competition with the highly developed railway systems, embodying the latest improvements of modern engineering, it is not to be wondered at that they have lost most of their former importance.

The only way in which canal navigation can be revived is to put it as nearly as feasible on the same footing as navigation in lakes and large rivers, by using large vessels, equipped with modern machinery, in channels of sufficient cross-section to keep the resistance to the movement of the vessels within economical limits. It goes without saying that canals of this description are very expensive to construct and maintain. There will, therefore, be but few locations on which the volume of the traffic will be sufficient to warrant their construction, and we may expect that but few canals will be built in the future, but they will be works of strictly the first class.

To the constructing engineer canal building offers many problems of great interest. The location of the canal, both from a commercial and a strictly engineering standpoint, requires careful study, while the excavation of the channel offers a field for introducing new and ingenious methods for handling earth and rock work on a large scale. The hydraulic questions involved, such as seepage, evaporation, problems of water supply, the flow of water in open channels, etc., are all interesting as matters of theory, and offer a rich field for experimental research.

In this paper it is not proposed to take up any of these topics, but to confine it to the subject of canal locks; not only because they are the most important structures in canal construction, but also because they have not been adequately treated in American engineering text-books.

GENERAL DEFINITIONS.

A canal lock may be defined as a structure which enables vessels to pass from a body of water to an adjacent one which is at a different level. As usually built, it consists of an enclosed basin or chamber provided with gates by which it may be shut off at either end, so that it can be put in communication alternately with the upper and lower levels. The method by which boats are passed through a lock is simple and readily understood.

Besides the ordinary canal lock, various other means for overcoming diffeiences of level in canals have been proposed at different times for at least one hundred years past. Among these may be

mentioned inclined planes and mechanical lifts acting vertically. A few inclined planes have been in use on small canals both in America and Europe for many years. Of vertical lifts a large number of projects have been worked out on paper, but only four of these have been built and are now in use. They are the hydraulic lifts at Anderton, England; Les Fontinettes in France and La Louvière in Belgium, and the floating lock, so called, at Henrichenburg, in Prussia. The largest of these is the last-named, which is 230 feet long by 28 feet wide, with a draft of water of 8 feet. The amount of lift is 52½ feet.

The operation of these lifts, the oldest of which has been in use for over twenty years, is quite satisfactory. Their principal *raison d'être* is the saving in water which they accomplish as compared with ordinary masonry locks. They are certainly of much interest, and in special locations their use will probably be more general in the future. The locks are, however, at best the most vulnerable portion of a canal system, and engineers may well hesitate before putting a more complex mechanism in place of the simple and massive masonry lock.

HISTORY.

The invention of the canal lock is one of the few great discoveries by which civilization has been measurably advanced. It alone has made it possible to navigate many important rivers and to carry canals over considerable elevations where a *single level* canal would be out of the question. The credit for building the first lock is claimed by both Holland and Italy, but the evidence as to time and place is conflicting. While in the plains of Northern Italy the navigable canal is the outgrowth of the shallow irrigating ditches used from time immemorial, the Dutch canal for boats has developed from the channels required to drain the low-lying fields or polders. In both countries simple sluices or head gates were built long before the enclosed lock with enclosed chambers. Such gates are sometimes used for navigation, and are often confounded with true locks by the earlier writers. The first clear and distinct description of a lock with an enclosed chamber is said to have been given by Leona Battista Alberti in his book entitled "De re. Aedificatoria," a copy of which was presented to the Pope Nicholas V in 1452. Simon Stevinus, the celebrated Dutch scientist, also gives a good account of a canal lock in a treatise published in 1618.

By other writers it is claimed that the first lock was built in 1481 near Padua, in Italy, while the advocates of Dutch priority feel confident that true canal locks were in use in the Netherlands before 1250. It may be added that the common canal lock is fre-

quently called the *Visconti* lock, from its alleged inventor, while by others the laurels of Leonardo da Vinci, already so ample, are increased by ascribing the discovery to the great painter. The exact date is, of course, not very important. It is of interest, however, to note that lock building, as well as canal construction generally, antedates the establishment of our profession by several centuries. In hydraulic works of all kinds many successive generations had accumulated a large amount of practical experience long before the civil engineer, as such, had come into being. In canal work a high degree of perfection was reached at least 150 years ago. Faulty methods in construction and operation had been gradually eliminated by the severe test of time and experience, so that the forms then in use have been followed pretty closely, as least for small canals, down to the present day.

Within the past fifty years many large locks have been built, but the principles of their construction are essentially the same as those followed in the older and smaller works.

Although the ordinary canal lock has often been criticised on various grounds, it cannot be denied that it has proved itself in practice an extremely satisfactory piece of mechanism. It is simple and durable, requires few repairs and is inexpensive in operation.

CLASSES OF LOCKS.

According to their location, locks may be divided into two general classes: (1) locks in inland canals and canalized rivers; (2) locks in maritime canals and harbors.

In the first class the difference of level to be overcome is due to the configuration of the ground, which makes it necessary to divide up the waterway into a series of pools or reaches at different levels. The "lift" in this case is practically constant, and the water pressure against the gates of the lock always acts in the same direction.

On the other hand, in locks used in harbors and in canals communicating with the ocean the difference of level is due to the tides, and in certain cases to wind action. In the North Sea-Baltic canal, for instance, there is a complete lock at the east end of the canal which is in use only about twenty-five days in the year,—at times when a strong east wind from the Baltic piles up the water in the outer harbor.

The principal use of locks in harbors is for closing dock entrances where the range of the tides is considerable. This is the case on the coasts of England and Germany, and on the Atlantic coast of France. The difference between high and low tide is rarely less than 15 feet, while in some localities, such as the ports in

the Bristol Channel, it reaches 44 feet at certain times in the year. In these harbors vessels are loaded and unloaded in enclosed basins surrounded by quay walls, in which the water is kept approximately at a constant level. These basins have narrow entrances, closed by one or more gates. In some of the docks, especially those of earlier construction, there is no enclosed chamber, so that the lock reduces to a mere pair of gates in the entrance channel. These gates are open for an hour or so at high tide, and all vessels must pass in and out at this time. When the tide in the outer harbor begins to fall the gates are closed, and keep the water in the dock basin from running out. In order to provide against exceptionally high tides in the outer harbor, another pair of gates is usually added, which are built so as to support water pressure acting from the outside. A further modification where the range of tide is great is the introduction of a "half-tide lock" with a second pair of gates, so that the pressure on each of them is reduced.

The limited time to which the traffic is confined in this form of dock entrance is objectionable, and many modern English docks are provided with complete locks having enclosed chambers, so that vessels can be locked through between the outer harbor and the docks at all hours. At high tide the gates are left open for some time, and the larger vessels usually come into the dock without locking.

The construction of these harbor locks is almost identical with the locks on large ship canals. In the leading ports of Great Britain a large number have been built during the last fifty years. In Liverpool alone there are more than one hundred pairs of lock gates for openings varying from 40 to 100 feet. As but few large ship canals have so far been built, it is to the experience gained in building these large dock gates that we must mainly look for guidance in designing similar works.

DIMENSIONS.

In designing a complete canal lock the first points to be fixed are the proper dimensions. These are the width, the length, the depth of water on the sill and the lift or difference of level between the water above and below the lock.

The width and length and the depth on sill are commonly the same for the whole canal, and depend on the maximum size of vessel employed. On the canal proper it is necessary to make the prism very much greater than the cross-section of the vessel, say from four to six times as great, so as to reduce the resistance to motion through the water to an economical amount. In the locks

this is unnecessary. An excessive size involves waste of water, increases the time required to operate the lock and greatly increases the first cost. In some cases, where the traffic is very heavy, locks have been built wide enough to allow two ordinary vessels to be docked side by side, and long enough to take in several of them one behind the other. The new American lock at Sault Ste. Marie, which is 100 feet wide and 800 feet long, is a so-called "fleet lock" of this kind. The wisdom of this design is doubtful. As the width and length of lake vessels is constantly increasing, it will not be very long before all the older and smaller vessels will go out of service, so that the 100-foot lock will not be wide enough to take in two of the vessels side by side nor long enough to allow them to enter "tandem." In that event the large dimensions of the lock will be worse than useless. The Canadian lock at the Sault, finished in 1895, is only 60 feet wide, but 900 feet long, and appears better adapted to the demands of traffic.

The probable size of vessels in the future is not easy to foresee, and the dimensions to be adopted for designing locks for large ship canals will vary greatly, according to individual judgment. Some thirty years ago the largest vessels were steamers with paddle wheels that projected a considerable distance on either side of the hull proper. To provide for these several locks 100 feet wide were built in the Liverpool and Havre docks. These are now wider than necessary. At present few merchant vessels are wider than 60 feet, although a few of the largest exceed this limit, and the "Friedrich der Grosse" is 68 feet wide. War vessels have somewhat greater beam, the "Iowa" of the United States Navy being 76 feet wide over all.

The locks on the North Sea-Baltic canal are 82 feet wide, while the new locks at Bremerhaven are to have a clear width of 92 feet, in accordance with a request of the North German Lloyd Steamship Company. On the Manchester canal 80-foot and 65-foot locks are used, although a still narrower lock is built at the side for small craft.

The proposed locks for the new Panama canal are to be 59 and 82 feet wide, and about the same width will probably be adopted at Nicaragua.

The depth of water on the sill of the lock should equal the maximum draft of the boats, with an additional clearance of 1½ to 2 feet.

The "lift" of a lock is its most important feature. If the width may be compared to the "length of span" in a bridge, the lift is analogous to the loading to which the bridge is subjected. The

lift or difference of level is fixed by topographical configurations, though in many cases the location of the canal is affected by the amount of lift which can safely be used. The inferior limit of the lift in a lock may be 1 foot or even less. The upper limit has not yet been reached. Very few locks with lifts exceeding 20 to 25 feet have ever been built. The greatest lift known to the writer in an inland canal lock is 30 feet. This lift is used at the new locks in the St. Denis canal, in France. In the Avonmouth dock at Bristol, England, the range of the tide is nearly 44 feet, and the strength of the gates is calculated for a head of 45 feet. This lock was built nearly thirty years ago, and though the gates are of timber their operation has been entirely successful.

The question whether lifts as high as 40 or 50 feet are advisable must be studied carefully for each separate case, and will depend on the supply of water, the density of traffic and other considerations, as well as on the structural difficulties involved. During the past year the writer has been engaged in the design of locks of various lifts up to 50 feet. So far as his plans have been matured, they show no reason why lifts of 45 or 50 feet could not be successfully used on locks as wide as 80 feet.

Such great lifts will seldom be needed, as the topography of the country passed through is almost always such as to make the majority of locks of moderate lift. Even where a concentration of the locks at a few points might otherwise be advantageous, this can rarely be done without flooding too large an area of valuable land. For this reason the opinion sometimes expressed that the adoption of mechanical locks which permit the concentration of the lift at a few points will always result in economy is a mistaken one.

CONSTRUCTION OF THE LOCK WALLS.

The construction of a lock may be divided into three parts: (1) the foundation, the side walls and the floor, which are generally built of masonry; (2) the culverts and valves for filling and emptying the lock, with the mechanism for operating the valves; (3) the lock gates and the machinery for moving them.

As in most structures, the nature of the foundation encountered affects the difficulty of construction to a high degree. Fortunately, in inland canals the locks can often be located on a solid rock bottom. In the case of harbors, on the other hand, rock is rarely encountered, and in many cases the bottom is extremely soft. The successful operation of the gates requires that the side walls and sill should remain almost absolutely true to their original lines. The difficulty of securing this result is greater than that encoun-

tered in building an ordinary quay wall. No general directions can be given as to the best choice of foundation in any given case. When the bottom consists of a rather firm sand or clay it is usual to cover the entire site with a layer of concrete of sufficient thickness to support the upward thrust of the water which may tend to lift it. This layer of concrete is laid in the dry when this is feasible, but must usually be deposited under water. The side walls are built on this foundation, and the portion between the walls forms the floor of the lock. When the bottom is softer and more variable piling must be resorted to, at least under the side walls, so that the weight of the walls may not tend to crack the floor. The problem of dimensioning the side walls and the floor when the bottom is soft is extremely complicated.

When built on solid rock a lock wall can be designed according to well-understood rules in the same way as a retaining wall. Each wall acts separately, and its weight is carried by the rock bottom immediately below it. The forces tending to overthrow the wall are the earth pressure behind it, to which must be added a certain amount of water pressure, varying with the permeability of the back filling. In this calculation the lock is, of course, supposed to be empty and the ground water to stand at its highest level.

When designing a lock to be built on a soft bottom we cannot calculate the strength of each wall separately, but must consider the entire cross-section of the lock—*i.e.,* the two side walls and the concrete floor—as a whole. This section is subjected to a variety of forces,—viz, the earth and water pressure on the side walls, the upward pressure on the bottom of the floor and the walls, besides the weight of the masonry and of the water in the lock. The magnitude and distribution of the upward reaction of the bottom cannot be exactly estimated. It is possible, however, to make a graphic analysis and draw a line of pressures in the walls and floor under various hypotheses. By comparing the conclusions to be drawn from this analysis with practical experience in locks built on a soft bottom much assistance can be gained in proportioning new structures. With the usual proportions the line of pressure at the middle of the floor is quite eccentric. This shows the existence of a considerable bending moment, which would tend to crack the floor at the top. Such longitudinal cracks have actually occurred in a number of harbor locks at the very points indicated by the theoretical analysis. They are not necessarily of a destructive character, and after they have been closed with concrete are not likely to give much further trouble. The structure after fracture is in a new position of equilibrium corresponding to a new distribution of pressure on the bottom.

Laying concrete under water is always somewhat unsatisfactory. In building the large locks at Holtenau, on the North Sea-Baltic canal, a simple but elegant method was used for lowering the ground water level and excluding the water from the lock pit. Three wells 12 feet in diameter were sunk by compressed air to a depth of about 15 feet below the bottom of the pit. They were placed close to and just outside the lock at three of its corners. By pumping from these wells with centrifugal pumps for a period of fifteen months the water level over the entire lock was lowered so that the foundation could be built entirely in the dry.

Compressed air caissons and open wells sunk by dredging have also been used for the foundations of harbor locks. The method used is practically the same as that employed for bridge piers. The locks at Toulon, Dieppe and some other French ports were built with compressed air foundations, while the Bordeaux lock was founded on open wells. In the latter case the close proximity of large warehouses was the reason for choosing this method.

The material used in lock walls is almost always masonry, but floors of timber construction are not unusual, even in large locks. Cut stone masonry is generally employed, though rubble with an ashlar facing is not uncommon. Of late years some locks have been built entirely of concrete. Among these are the fine locks recently completed by the United States Government on the Hennepin canal in Illinois. The writer has also had occasion to examine the masonry recently built for the new guard gates in the St. Mary's Falls canal. This masonry consists of a rich concrete without any cut stone, and presents a very good appearance. The gates are of timber, and span a clear opening of 108 feet. This is a greater width than any known to the writer elsewhere.

The masonry at the ends of a lock must support the pressure from the gates. The walls at the ends are necessarily thicker than the side walls of the chamber, and must be built with extreme exactness, so as to fit the gates. Their details will depend on the style of gate used.

The construction of the masonry is further complicated by the necessity of inserting culverts for the filling and emptying of the lock, and also of tunnels for the cables that move the gates and the pressure pipes connected with the operating machinery.

ARRANGEMENTS FOR FILLING AND EMPTYING THE LOCK.

Three different plans are in use for this purpose: (1) valves in the upper gate; (2) side culverts in the lock walls; (3) culverts under the floor of the locks.

The first plan has the merit of simplicity, and is generally used in small locks. The openings are rectangular and placed as low as possible in the gates, so as to act with the largest possible head. The valves are simple sluice gates, operated by hand from the top of the gate. Such openings weaken the gate where the water pressure is greatest. Another objection is the fact that the water rushes in with much velocity, and tends to break the cables of vessels in the lock. Furthermore, the time required to fill a large lock by valves in the gates is excessive. For this reason such valves are supplemented or replaced in most large locks by culverts in the side walls or under the floor. The latter arrangement can be conveniently adopted only in case of a rock foundation, to which the floor system can be bolted down to resist the upward pressure of the water, tending to lift the floor when the culverts are filled. The most important examples of such culverts are found in the three great locks at Sault Ste. Marie. In all of these the water is admitted through large rectangular culverts under the floor. They are about 8 feet square, and connect with the lock chamber by a large number of openings along the bottom of the lock. The culverts run side by side, and are built of solid timbers. There are two culverts in the smaller American lock, six in the larger and four in the Canadian lock. The head is about 19 feet. The largest lock is filled in about eleven minutes, using four culverts only.

Side culverts are general in the larger European locks, such as those in the Manchester and North Sea-Baltic canals. There is a culvert in each wall about twice as high as it is wide. In the Manchester canal the size of the culverts is 6 x 12 feet. They discharge into the lock by lateral openings.

In connection with culverts three classes of valves are used,—viz, slide valves, butterfly valves and cylindrical valves. The first class are rectangular, and may be built of either metal or wood. It is desirable that they should move with little friction, and be as nearly water-tight as possible. On the Manchester canal the Stoney sluice gates are very successfully used, in which the friction is largely reduced by a system of roller bearings. In the North Sea-Baltic canal a similar sliding gate built of timber was adopted. In American locks butterfly valves revolving on a central axis are common. They are simple in design and durable, and require but little power to operate them. The only objection to their use is the excessive consumption of water, as they cannot be made with a tight fit. This precludes their use where water is scarce.

Cylindrical valves are in use on many French canals, and have been proposed for the enlarged Erie canal. They consist of vertical

steel cylinders resting on conical seats, and are raised vertically to admit the water through an annular orifice.

While these valves have many good features, they are quite expensive, as the amount of water that can pass through any one valve is comparatively small. Valves are generally operated by power, the machinery being combined with that for moving the gates.

LOCK GATES.

Although they represent a relatively small part of the total cost, the gates are more complex in construction than any other part of the lock, and on their correct design its successful operation will largely depend. Considered merely as structures, they present an interesting field in the theory of stresses and in practical designing.

Every lock with an enclosed chamber must have at least two gates,—one at each end. Besides this an intermediate gate is frequently added, which permits the working length of the lock to be shortened so that smaller vessels can be locked through more quickly and with less waste of water. Quite generally, too, a guard gate is built at either end to allow the entire lock to be laid dry for periodic examination and repair.

Lock gates, whatever their detailed design, are really movable dams, and when closed support the pressure of a considerable head of water. The standard form used in the great majority of cases is the mitering gate. This consists of two leaves, each turning on a vertical axis, like an ordinary door. When closed the leaves meet at an obtuse angle, the so-called toe posts abutting against each other in the middle of the lock, while the bottom of the gate rests against a continuous sill. When in this position the two leaves act as an arch which conveys the water pressure to the side walls. The fitting of the gates against each other and the sill is difficult to make and maintain uniform at all times. A bad fitting may interfere with the proper working of the gates, and also causes the stresses in the different members to be somewhat uncertain.

For these reasons, among others, many substitutes for mitering gates have been proposed, and some of them carried into execution. The more important of these forms may be briefly referred to.

(1) The single leaf revolving gate. This consists practically of one leaf of a mitering gate long enough to reach across the lock at right angles; the gate is supported on the bottom and both sides, and acts as a girder or truss instead of an arch. The single leaf is, of course, heavier than the separate leaves of a mitering gate for the same opening. It requires much more power to move, and also

shortens the available length of the lock which can be occupied by vessels. The cost is about the same as for double-leafed gates. Single-leafed gates have of recent years been built in France up to 50 feet in length.

(2) The "Tumble" gate, which also spans the canal with a single leaf, but revolves on a horizontal shaft fixed at the bottom of the lock. This form has been used in some of the Erie canal locks for many years.

(3) Sliding gates. Gates of this kind have been built in different English and continental harbors, and in this country in connection with the Davis Island dam in the Ohio River improvement. The foreign gates are of iron with closed air chambers, while the Davis Island gate which spans an opening of 110 feet is of timber framing. These sliding gates when closed act as trusses, supported by the side walls and the sill. They are opened by moving them sideways at right angles to the lock into a recess constructed in the masonry wall on one side.

(4) Pontoons. Pontoons are sometimes rectangular gates like the sliding gates just referred to, although they may also be built having the curved outlines of an ocean vessel. They are floated across the lock entrance, and are sunk into position by letting water into tanks provided for the purpose. When the lock is to be opened they are moved into recesses in the wall. Pontoons are used generally in dry docks, but are not well adapted for ordinary canals where rapid and frequent moving of the gates is required. The same may be said of the sliding gates, although the latter, if properly designed and fitted with a good moving mechanism, would probably give satisfaction in canal work.

The ordinary mitering gate has, however, in the writer's opinion, so many strong points, such as lightness and facility of movement, that it is likely to hold its own even for large locks.

MITERING GATES.

Mitering gates are built of all sizes, from the great gates spanning openings of 100 feet down to the smallest guard gates. The material used in their construction is timber or iron, or a combination of the two. For small gates timber is in every way preferable, as the first cost is less, repairs are more easily made and there is no difficulty in designing gates of simple construction using timbers of small scantling and length. A number of small iron gates have been built in different countries, but the prevalent opinion among the engineers directly in charge of canals seems to be averse to their general adoption.

The general use of steel in bridges and ships makes large wooden lock gates seem somewhat out of date. Metal would appear to have great advantages as in other engineering structures. Large iron gates have, as a matter of fact, been in use for over fifty years, the first wrought iron gate having been built for a 60-foot dry dock entrance in the Brooklyn Navy Yard about 1850, while about the same time similar gates were constructed by English engineers at Sebastopol, Russia, and by the Germans in the Bremerhaven docks. It has never been denied that these and later iron gates have given perfect satisfaction.

It is true, nevertheless, that many English and American engineers of great experience in lock work remain strongly prepossessed in favor of timber gates. In England, even at the present day, about half of the new gates are built of wood. In the Manchester canal green heart timber, a very durable wood brought from British Guiana, was used exclusively in the fifty-four gate leaves built, although the cost was much greater than that of iron gates would have been. Some of the large American gates, such as those in the new Canadian lock at the Sault, are also built of wood.

Apart from natural conservatism, the reasons which make for wooden gates are their greater lightness, which makes them easier to move, and still more the ease with which they may be repaired in case of a collision. Such accidents are always possible, although they are rare. It does not seem to the writer that this contingency is sufficiently probable to make it wise for us to give up the great advantages of steel gates.

DETAILS OF CONSTRUCTION.

A mitering gate consists of a skeleton or *frame* and a *water-tight* sheathing. The frame may be arranged in different ways, but there is always a heel or quoin post close to the masonry, a toe or miter post at the other end of the leaf and two horizontal girders, one at the top and another at the bottom of the gate. Besides this there are usually a number of intermediate horizontal girders forming a series of arches or rafters carrying water pressure. In a few gates vertical girders, which bear against the top horizontal girder and the bottom sill, take the place of the intermediate horizontals. The weight of the gate is supported on a vertical pivot fastened to the bottom of the quoin post, while at the upper end of this post there is an anchorage which extends into the masonry wall. A roller traveling on a circular track on the bottom of the lock has in the past been quite generally used at the outer end of large gate leaves. This relieves the pivot and anchorage of much weight, but

makes distribution very uncertain. The disadvantages of rollers have led to their gradual abandonment.

TIMBER GATES.

The sheathing is always made of planking with calked joints. The posts consist of one large timber or may be built up of several pieces. The horizontals differ in construction according to the size of the gate. For moderate spans straight horizontals made of a single timber can be used, but for larger gates built-up trusses must be employed. Where long timbers can be had, bowstring girders with wooden tie beams, or preferably with iron tie rods, are probably the best form to be adopted. As examples of such girders, the old gates for the 100-foot dock entrances at Liverpool and Havre and the Weitzel lock at the Sault (60 feet wide) may be referred to. The gates in this last lock have been renewed during the past winter. They were designed by Mr. Alfred Noble, M. Am. Soc. C. E., and completed under his care in 1881. The iron rods, pivots, etc., were found to be in perfect condition and have been used for the new gates.

Where long timber is difficult to obtain, the horizontal girders may be built up of several short lengths framed between vertical intermediate posts and bolted to reinforcing timbers. Many English gates are built in this way.

IRON AND STEEL GATES.

Iron or steel gates, like timber gates, consist of a frame and a sheathing, both of metal. The cushions at the quoin and miter posts and the sill where water-tightness is required are usually made of wood.

The design of a steel lock gate, like that of any other structure, is largely dependent on the forces which it has to resist. These will be different when the gate is opened and when it is closed. When open, the gate exerts a horizontal pull on the anchorage, while its weight rests on the pivot. These forces must be transmitted through the gate frame and are readily analyzed.

When the gate is closed the water exerts a horizontal pressure, which is transferred by the gate to the side walls and sill of the lock. The magnitude of this pressure is easily determined, being at each point equal to the hydrostatic head. The upper gate is most strained when the lock is entirely empty. The pressure increases from 0 at the top to a maximum at the bottom, and may be represented by a triangle.

In the lower gate it is 0 at the top, increasing uniformly to the

level of the lower pool, and from that point is a constant to the bottom of the gate. It may be represented by a trapezoid.

The gate can be designed to stand this pressure in various ways. The most common form consists of a series of horizontal girders spaced in an approximately equal manner and fastened securely to the quoin and miter posts. They are further held in place by vertical frames, intermediate between these posts, which add greatly to the stiffness of the gate. The sheathing consists of plates riveted to the horizontals and calked at all joints to secure water-tightness. This sheathing is required only on one side as far as the function of the gate as a dam is concerned. It is a very general practice, however, to place the covering on both sides, forming a series of air-tight compartments, the flotation of which relieves the pivot and anchorage of weight and makes the gate easier to turn. Some of the chambers are also filled with water as ballast.

The closed chambers are hard to keep tight and somewhat inaccessible. For this reason in some of the latest designs, such as the Cascade locks on the Columbia River and the Plaquemine locks in Louisiana, both built by the United States Government, they have been omitted and the gates built with a single skin only.

In beginning the actual design, the first point to be settled is the rise of the sill, which fixes the angle which the gates make with the axis of the lock. The rise varies from $\frac{1}{3}$ to $\frac{1}{6}$ of the width in various locks, but a rise of $\frac{1}{5}$ is perhaps the best, being as economical as a greater rise.

The next point to be considered is the proper outline of the horizontals. These are almost always plate girders, and may either have a straight girder shape or else follow the lines of an arch, the medial line of which is a circular curve passing through the center of the quoin and miter posts.

Each horizontal is in equilibrium under three external forces, —viz, the water pressure, which is uniform and normal to the face of the gate, the reaction of the other leaf, which is at right angles to the axis of the lock, and the reaction of the masonry at the quoin. These two reactions are equal and make the same angle, with a line connecting the center of pressure at the quoin and miter posts.

If the gate consisted of a linear arch without thickness, a circle would be the true line of equilibrium for the forces acting on it, and the arch would be in pure compression, and hence the most economical shape. On these theoretical grounds, it has generally been held that an arch gate of circular shape is necessarily the most economical. This has been stated by many different writers for

fifty years back, and the proposition has been reinforced by many intricate calculations, involving the use of the higher mathematics.

As a matter of fact, the gates are never linear arches, but must be built as curved beams which are rarely less than 3 feet in thickness, so that the surface submitted to the water pressure is not identical with the curved axis of the horizontal girder. Furthermore, the center of contact or pressure where one leaf presses against the other at the miter post is rarely exactly on the medial line, but, on the contrary, varies considerably on either side. This difference of position is due both to unavoidable inaccuracy in fitting and material and also to the change in the length of the gate leaves at different times, owing to variations in temperature. As a result of this, the circular arch is never in pure compression, but also subject to considerable cross-bending. Besides this, in proportioning engineering structures many practical considerations, such as the minimum thickness of metal that may be used, etc., must be taken into account, so that any general theoretical deduction loses still more in value.

The only reliable method of comparison for different shapes consists in a series of estimates based on actual detailed designs. By means of several extended estimates of this kind, the writer has satisfied himself that, at least for locks up to 80 feet in width, the circular arched gate is no more economical than the straight or girder shape, while it has many practical disadvantages.

The dimensions of the web and flanges in any given girder are to be determined by the rules commonly used where there is a combination of compressive and bending stresses.

Another interesting question is the distribution of the total water pressure over the different horizontal girders. The total amount of this pressure for the whole gate is perfectly determinate. In case the horizontal girders were connected by a flexible sheathing, the distribution would be equally simple, each girder getting exactly the load due to its head below water level. As actually built, the girders are connected by sheathing that has some stiffness and by vertical posts that have much rigidity. Furthermore, the bottom of the gate fits more or less closely against a solid sill. The stiff vertical members modify the distribution of the load over the different horizontals, even when there is no contact on the bottom sill and still more when there is contact, so that the verticals carry some of the water pressure to the bottom sill. The result is that the upper part of the gate is more fully loaded, while the lower horizontals are proportionately relieved.

Some interesting experiments on models made by M. Chevalier,

in France, in 1850, illustrate this point very beautifully. The mathematical statement of these complex stresses has been attempted by several French engineers, but their methods are very intricate, and the results, while indicating correct values, hardly merit extreme confidence.

The method of "Least Work" for solving indeterminate stresses has been applied by the writer to this question with results that agree satisfactorily with some measurements he has made during the past year on the deflections of large gates.

French engineers commonly design the lower girders of their gates in accordance with the formulæ referred to above, assuming simultaneous contact at the miter post and the sill at all times, while in England it is usual to proportion each girder for its full hydrostatic head. As the close fitting at the sill is likely to fail at times, the English practice seems the safer one, though the upper part of the gate should be strengthened rather more than is customary in some of the English gates.

The details of construction in all parts of the gate will, of course, vary according to the individual judgment of the engineer in charge.

Many otherwise good gates are unnecessarily complex in construction, showing a lack of familiarity with shop practice on the part of their designers.

In lock gates, which are machines rather than structures, facility of operation and freedom from breakdowns are far more important than first cost. At the same time a gate that is simple in detail is also likely to be satisfactory in daily use.

MACHINERY FOR OPENING AND SHUTTING THE GATES.

The methods used for opening and shutting the gates can only be briefly referred to. In large modern locks the machinery is always operated by power, in order to shorten the time required. The prime movers are generally turbine wheels, operated by the water in the canal at the head equal to the lift of the lock. The power thus generated is transmitted to the mechanism for moving the gate by water under pressure, by compressed air or by electricity. In the past water under pressure varying from 100 to 800 pounds has been generally used. Machinery of this kind was first designed by Sir William Armstrong for English harbor locks, and includes the use of his well-known accumulator. Most English plants have been constructed by this firm, and designers in other countries have generally used very similar forms. The water under pressure moves reciprocating pistons to which cables are

attached, or else rotary engines, usually with three cylinders, are used.

The turning of the gates is generally effected by steel cables or chains, which are attached close to the miter post near the bottom of the gate. One cable serves for opening and another for closing. The cables are brought to the engines on the top of the lock walls through tunnels built in the masonry. The details of the attachment and general arrangement differ in various designs, but it is usual to have an independent engine on each side wall.

Although cables and chains have worked very satisfactorily, they have some disadvantages, and in several recent locks other appliances for opening and shutting the gates have been adopted; thus, in the new locks at Barry, in England, a stiff strut is used which is attached to the gate above the surface of the water, and serves both to open and shut it. One end of this strut connects directly to a plunger that moves in a hydraulic cylinder. This cylinder oscillates on a double axis, which is placed in a recess built in the wall approximately at right angles to the face of the wall. In the North Sea-Baltic canal, and also in the new lock at Ymuiden, at the west end of the Amsterdam canal, a similar arrangement is used, but the strut is not directly moved by hydraulic power, but carries a rack that connects with geared spur wheels.

Quite recently electric motors have been substituted for water pressure engines, and the use of this power is likely to become general. Hydraulic machinery in cold climates is always likely to give trouble, and in some instances it is necessary to use oil in place of water during the spring and fall before it becomes necessary to cease operating entirely. Besides this the transmission of power by pressure pipes to distant parts of the large lock involves expensive construction, and repairs are frequently needed. The use of the electric current would seem to obviate all these difficulties. In the Canadian lock at Sault Ste. Marie electric motors are used for opening and shutting the gates, as well as operating the large valves in the culverts. The operation of this machinery is entirely satisfactory, although it seems to be rather complicated.

Electric power has also been adopted for the gates of the new lock at Ymuiden, on the Amsterdam ship canal, as a result of an extended series of experiments. We may expect that in the future most new locks will be operated as well as lighted by electricity.


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
CAL.
NEV.
UTAH
COLO.
NEBR.
IOWA
KAN.
MO.
ILL.
IND.
OHIO
W. VA.
KY.
MD.
VA.
N.C.
TENN.
S.C.
ARIZ.
N. MEX.
OKLA.
IND. TY.
ARK.
MISS.
ALA.
GA.
TEX.
LA.
FLA.
ME.
MASS.
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC OCEAN

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. OCTOBER, 1899. NO. 4.

THE FLOW OF WATER IN PIPES.

By C. H. TUTTON, MEMBER ENGINEERS' SOCIETY OF WESTERN NEW YORK.

THE substance of the following paper was originally read before the Engineers' Society of Western New York, in April, 1896. There was a very glaring absurdity in it as then prepared which escaped notice until after it was ready for distribution, and the author was also taken to task by some of his critics on the charge of levity. While the present paper may be somewhat open to this charge, we shall endeavor to avoid much of that used before, confining it to our quotations.

The attempt will be made to show that the Torricellian formula, $v^2 = 2gh$, is misapplied in the fundamental stages of the science of hydraulics; and while it is recognized that the author may be wrong, he would ask, if such be the case, how can the many agreements of his deductions, which seem too numerous to be accidental, with what has heretofore been regarded as entirely within the domain of experiment, be accounted for?

Weisbach demonstrated the Torricellian theorem substantially as follows: If the head h be constant, the velocity of efflux being v, and the discharge per second being Q, w being the weight of an unit of mass, the weight of the liquid discharging will be Qw. The work which this quantity of liquid can perform while sinking through the distance h is Qhw, and the energy stored by the discharge, whose weight is Qw, in passing from a state of rest to the velocity v is $\frac{v^2}{2g}$ Qw. If no loss of mechanical effect take place during the passage through the orifice these quantities of work are equal to each other, whence we obtain $v^2 = 2gh$.

The more modern demonstration is: Suppose the head h be constant, then the potential energy of the mass is $F = mgh$. The kinetic energy of the issuing mass is $E = \frac{1}{2}mv^2$. If these be placed equal, then $v^2 = 2gh$; or, in other words, we have the remarkable result that the velocity of the issuing water through a horizontal orifice varies directly as the square root of the acceleration of gravity by *twice* the head.

From this result it can be shown that the pressure at the orifice is equal to the weight of a column of water whose area is that of the orifice, and whose height is *twice* the head. Bazin has proven this false experimentally. (See "Contraction of the Liquid Vein," Trautwine's translation, p. 32.)

That the first result is not true is shown in the simplest experiment with an orifice, the quantity discharged never being equal to the area of the orifice by the velocity as deduced by this equation.

As Mr. Robert D. Napier says (*Engineering*, Vol. XXI), "First of all a theory is adopted, which makes out that a certain amount of work should be done; then a double-headed phantom is invented to do the proposed work; then, because the work is in reality not done, it is argued that that arises mainly from the fact that the phantom is in such a hurry to do its work that it trips itself up and blocks up the orifice it is trying to get through."

The same gentleman says, in Vol. X, No. 1, of the "Proceedings of the Philosophical Society of Glasgow," "I have proved . . about three-eighths of the ultimate velocity and five-eighths of the *vis viva* is imparted to the water outside of the plane of the orifice."

M. Bazin (p. 27 of work before referred to) speaks of the rapidity with which the velocities vary from the plane of the orifice in a distance equal to its radius from it, when "they are completely equalized throughout the entire cross-section." He also says, p. 39, that "the formula $v = \sqrt{2g(h + y)}$ is no longer rigorously exact from a theoretical point of view."

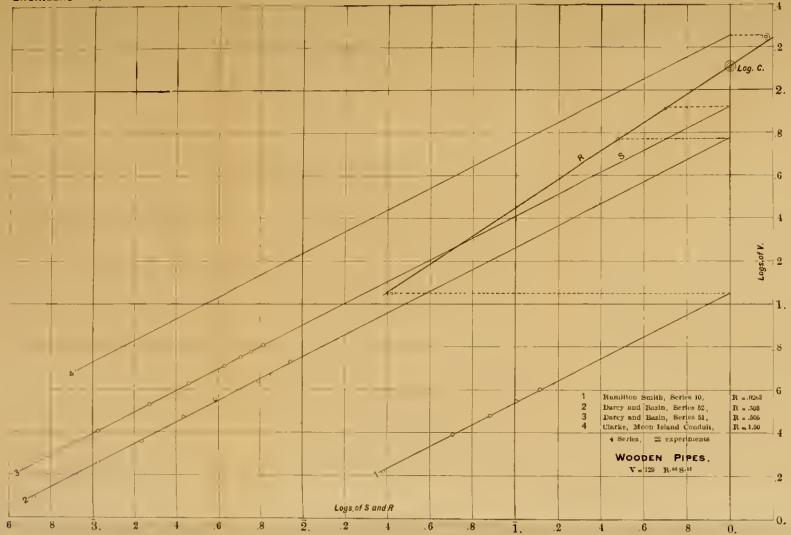
Professor Heinemann (*Van Nostrand's Magazine*, Vol. VI, p. 198) attacked the theory above presented, arriving impliedly at $v^2 = gh$, this in turn being attacked by Professor S. W. Robinson, who defended the original theory. In any event, both of these require a correction usually expressed by a symbol representing the so-called coefficient of contraction, deemed essentially one of experiment, and assuming a contracted vein which Bazin states (p. 36 of work before quoted) does not exist.

Professor Hele-Shaw, in the *Engineer*, June 2, 1899, states that "it is extremely convenient to treat all kinds of resistance as following the same law,—viz. square of velocity, which the varia-

FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899 C. H TUTTON

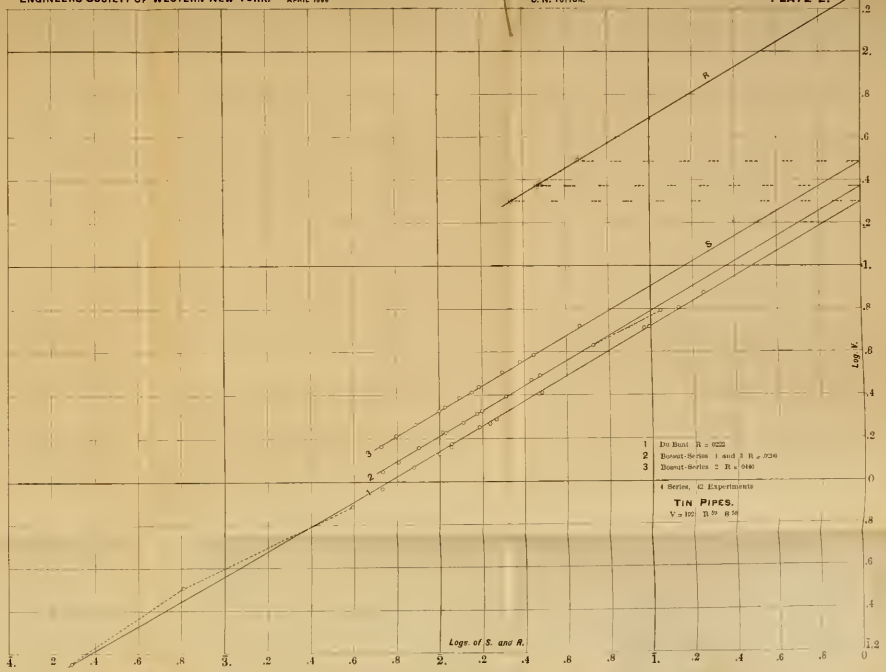
PLATE 1.



FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899 C. H. TUTTON.

PLATE 2.



the so-called coefficient of contraction, deemed essentially one of experiment, and assuming a contracted vein which Bazin states (p. 36 of work before quoted) does not exist.

Professor Hele-Shaw, in the *Engineer*, June 2, 1899, states that "it is extremely convenient to treat all kinds of resistance as following the same law,—viz. square of velocity, which the varia-

tion of head or height of surface has been shown to do. But this is far from being exact, and an enormous amount of labor has consequently been expended in finding for all conceivable conditions in actual work tables of coefficients," etc.

Now, both of these, and, in fact, all theories so far presented, imply that the mass *above* is that directly *over* the orifice, since they require a mass equal in area to that of the orifice, transferred through the height h in each element of time. Is this correct? Is not our so-called coefficient of contraction a necessity of physical laws, and susceptible of direct calculation rather than an empirical constant?

Suppose A, B be the free surface of a mass of liquid, and O be a point in the bottom of the containing vessel. Now, all of the pressure that can possibly be brought to bear on the point O is, by the principle of equal transmission of pressure, bounded by a hemisphere whose radius is equal to the head. But the center of mass of this hemisphere is $\frac{3}{8}$h distant from the base, whence the potential energy would be $mg\frac{3}{8}h$; and equating this with the kinetic energy $\frac{1}{2}mv^2$ we obtain $v = \sqrt{2g\frac{3}{8}h} = .6124\sqrt{2gh}$ in the plane of the orifice. Bazin's experimental value for this coefficient with orifices 4 to 8 inches in diameter is about .604, while Ellis found for larger diameters about .601. The difference of about 1½ per cent. can be accounted for in the fact that the coefficient above applies solely to a point, which would be the fundamental constant for horizontal orifices with a perfect liquid. We also learn from this that the pressure at the orifice is three-quarters instead of twice the head, confirming the results of Napier and Bazin.

This velocity is that immediately at the orifice. At the instant of passing the orifice an entire release of pressure takes place. The elasticity of the water, supposed perfect, must now restore it to its original volume. The original compression was due to a head h, but three-eighths of this has been used to give velocity at the orifice. The remaining portion, or five-eighths h, must now be restored in expansion, which gives the total head h; and, as $\frac{1}{2}mv^2 = mgh$, we obtain for velocity *beyond* the orifice $v^2 = 2gh$, which, as Bazin states, is entirely gained in the distance r; but while the first expression, $v = \sqrt{2g\frac{3}{8}h}$, applies in the plane of the orifice, the second applies only to the individual particles which have passed through it, the discharge being free into the air and vertical.

As the present object, however, does not concern orifices directly, this part of the subject will not be pursued further.

In speaking of this Torricellian theorem as applicable to river velocities, Major Allan Cunningham, of the Royal Engineers, says

("Roorkee Hydraulic Experiments," Vol. I, p. 145), "For fully a century after Marriotte's time this notion (founded on a supposed but false analogy) proved the most complete hindrance to the science of hydraulics; the double float has certainly done one good service in disproving this notion."

Let us now take up some of the formulæ for the flow of water in pipes, and first the time-honored Chezy formula. (In using the term pipes understand only a closed conduit which is filled at the discharge end, consequently the inlet end must be entirely submerged.) M. Chezy's formula was proposed for open channels, but should be equally, or even more, applicable to pipes.

Adopting the theory of uniform motion, and that in order to obtain such motion the resistance must be equal to the motive force, he assumes, first, that the resistances are directly proportional to the length of the wetted perimeter, multiplied by the length of channel. He also considers them proportional to the square of the mean velocity, since by an increase of velocity a greater number of particles are separated in a proportionally less time, or the total resistances may be expressed by kv^2lp. The motive forces he assumes proportional to the effective component of the weight or to agh, a being the area, g the acceleration of gravity and h the fall in the distance l. Equating these we obtain $kv^2lp = agh$, whence $v = \left(\frac{gha}{klp}\right)^{\frac{1}{2}}$ or calling $\frac{h}{l} = S$, and $\frac{a}{p} = R$, the so-called hydraulic radius

$$v = C(RS)^{\frac{1}{2}}.$$

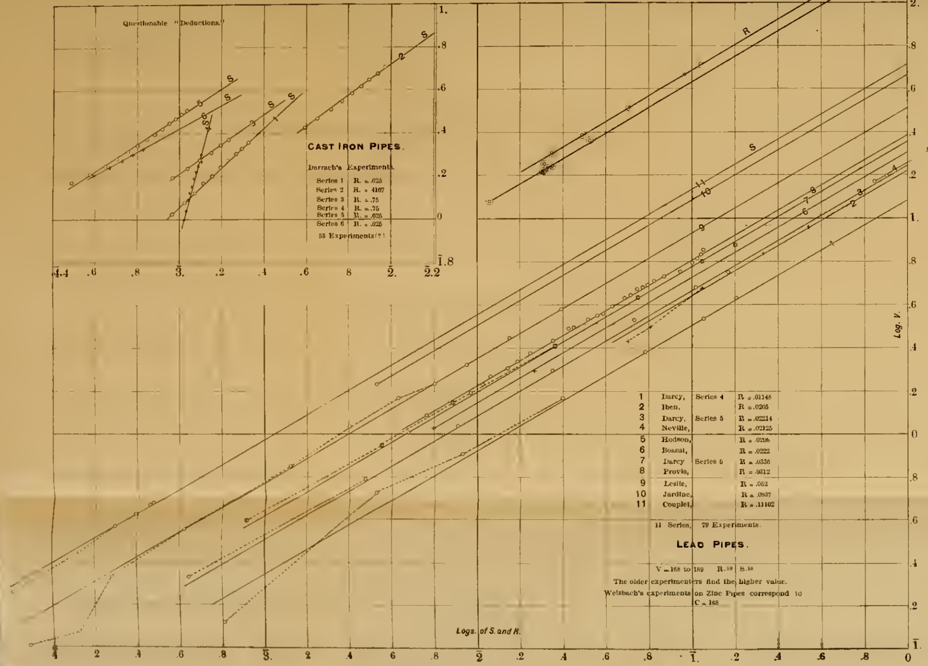
Instead of analyzing experiments as a whole, analysis to find a value of C suitable for this equation has engaged the attention of very many hydraulicians.

It is proper to remark here that the former method of calling S the sine of the slope is both misleading and faulty. S is the head or fall divided by the length of the pipe; it may be the sine of the slope or may be the tangent. Generally it is neither, but a hybrid. It is an element designed to take into consideration the total frictional or wetted surface of the pipe, R only taking into consideration a section. Later writers designate it as the virtual slope.

Suppose a different assumption be made. The fiction of the hydraulic radius will be preserved, since it has been experimentally shown that in closed pipes the velocities are symmetrically distributed around the center of figure. (I am only aware of four series of experiments on pipes other than circular, and they seem to conform to this law. In comparing circular sections, any linear element, as well as a divided by p, could be taken as the unit of reference.) Assume a plane perpendicular to the direction of flow,

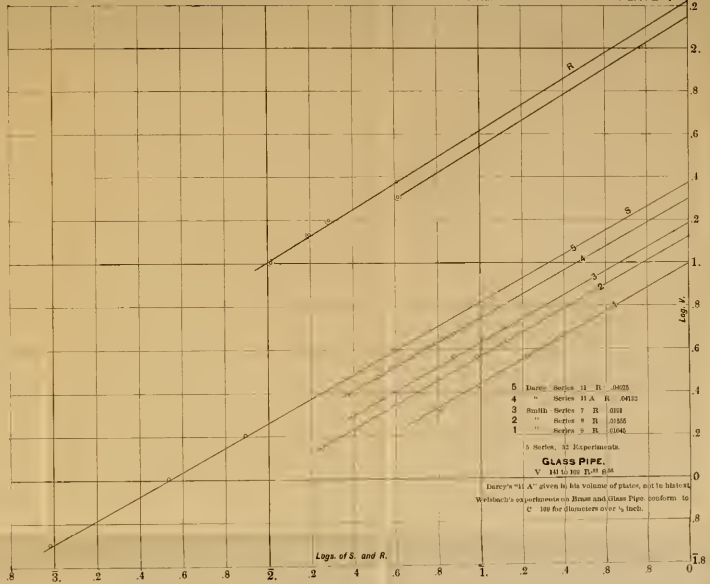
FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899. C. H. TUTTON. PLATE 3.



FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899. C. H. TUTTON. PLATE 4



to conform to this law. In comparing circular sections, any linear element, as well as a divided by p, could be taken as the unit of reference.) Assume a plane perpendicular to the direction of flow,

and let us also assume that the mass of water below this plane is offering a resistance to the motion of that above and is being pushed by it. We will then have, if we consider R as the edge of some elementary cube opposed to this pressure, $P \propto R^3$. But, according to the law of free fall, $P \propto h \propto v^2$, hence $v^2 \propto R^3$, or $v \propto R^{\frac{3}{2}}$, and assuming v also to vary with $S^{\frac{1}{2}}$ and making C the general constant,

$$v = CR^{\frac{3}{2}} S^{\frac{1}{2}}.$$

In this shape the formula is used by many river engineers.

TAKE AN ENTIRELY NEW ASSUMPTION.

If we consider the transporting power of the pressure and have P, the pressure required to just move the cube, whose edge is R, we have, as above, $P \propto R^3$. But, as this impulse is proportional to face area and square of velocity (?), we also have $P \propto v^2R^2$, whence $R \propto v^2$ and hence $P \propto v^6$. This may be termed the value of the pressure as connected with its transporting power, or the pressure exerted on the mass of water ahead of any section owing to the velocity of that above it, a condition fully realized in pipes with vertical curves, as inverted siphons.

Now, considering only the ordinary resistances, generally called frictional, of the pipe, the losses due to entrance, bends, etc., having been separated, we find that while in solids the friction varies as the mass, but is independent of the surface, that in liquids it varies as the surface, but is independent of the mass. We have, then, since the surface also varies directly as the velocity, $f \propto v \propto R^2$, and knowing from the law of free fall that $p \propto v^2$, we have $p \propto R^4$, the value of the pressure as overcoming resistance. But since we must have $p = P$, therefore $v^6 \propto R^4$, or $v \propto R^{\frac{2}{3}}$; and again assuming v to vary as $S^{\frac{1}{2}}$, which from the general law of free fall we are justified in doing, we have $v \propto R^{\frac{2}{3}} S^{\frac{1}{2}}$, whence we can write

$$v = CR^{\frac{2}{3}} S^{\frac{1}{2}}.$$

The way the value of the constant C was originally determined is as follows: If in the equation of variation $v \propto R^{\frac{2}{3}} S^{\frac{1}{2}}$, we make the first term definite by the introduction of the mass $\frac{w}{g}$, the second member will also become so by the introduction of a coefficient of resistance $\frac{1}{f}$, whence

$$\frac{w}{g} v = \frac{1}{f} R^{\frac{2}{3}} S^{\frac{1}{2}} \text{ or } v = \frac{g}{wf} R^{\frac{2}{3}} S^{\frac{1}{2}}.$$

This assumption has been opposed on account of lack of homogeneousness in the equation. We will grant this lack, provided it can be shown just what f represents. It is not friction alone; it is not viscosity alone. The element of weight necessarily enters into it, as also the element of time. We are, however, willing to allow the expression to stand as empiric until f is analyzed.

While we could say we hunted for a suitable value of C, the simple way in which we arrived at just the value required on the first trial is worthy of note.

This form has been submitted by Gauckler, by Hagen, by Heinemann, by Foss, by Thrupp, by Vallot, and still later by W. Santo Crimp and C. E. Bruges, but none of whom, to my knowledge, has attempted to justify it theoretically or presented it other than as an empiric formula for special cases.

If we put the average values of w and g in this, or w equals 62.42 pounds, g equals 32.16 feet, we obtain $v = \frac{.513}{f} R^{2/3} S^{1/2}$.

Now, *simply for convenience*, and in order to use about the same value of n as given in Kutter's complicated formula (in justice to the Kutter formula we will state that it was not designed for pipes), multiply this coefficient by 3, and calling $3f = n$ there results

$$v = \frac{1.54}{n} R^{2/3} S^{1/2}.$$

a formula which, for ordinary purposes, is equally accurate with and of as wide application as Kutter's, but which, with his, fails in extreme cases. n will not rigidly follow his values, yet in many cases it is even more steady. For values from $n = .008$ to $.018$ it may be taken the same. Getting much above these values, either in Kutter's or this formula, there is no more danger of error in estimating C direct than there is in estimating n, if we get in the habit of thinking C as we have of thinking n. If proof be desired, read the tables of n in Trautwine and Hering's "Kutter," where, while C varies from 125 to 188, n varies from .0218 to .0452, or C varying from 45 to 94, n varies from .0296 to .0425. I have used this formula for nearly six years in the form $v = \left(\frac{1.54}{n} - \frac{2}{R}\right) R^{2/3} S^{1/2}$, as this correction makes it more suitable for small hydraulic radii (more especially in open channels) when n is considered constant for the same class of surface. For large R the correction disappears.

With $n = .013$ Kutter's value for brick sewers, the above would become $v = 118 R^{2/3} S^{1/2}$, while Messrs. Crimp and Bruges give 124 for the constant term.

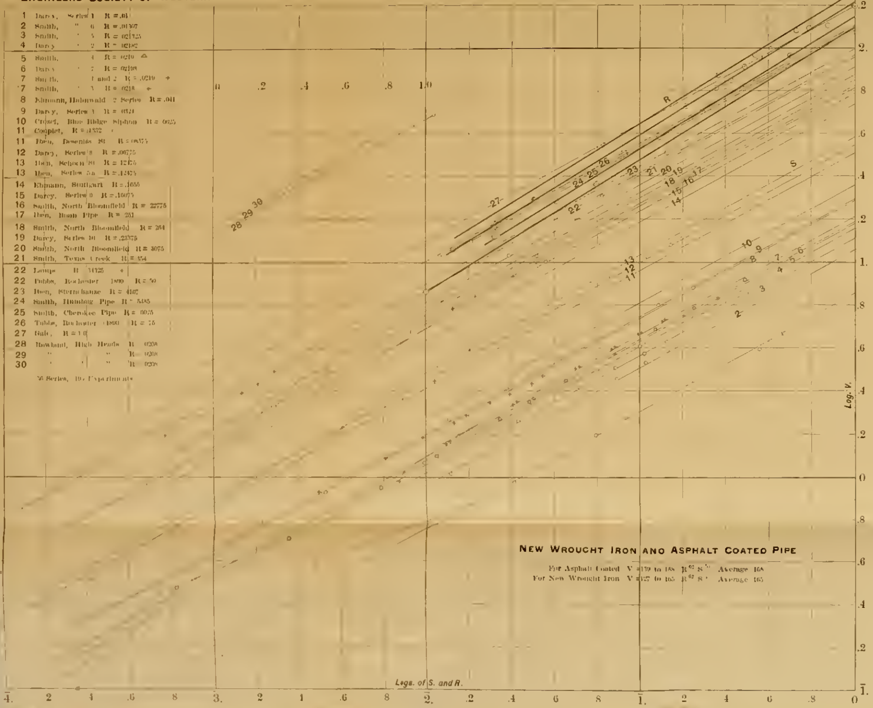
Incidentally, it should be stated that it is just as applicable to open channels as to pipes, under the ordinary assumption that R equals the area divided by the wetted perimeter.

To make a few comparisons:

Mr. J. C. Quintus measured the discharge of the Niagara River at this place. From his measurements are deduced $R = 22.89$, $S = .000144$, $v = 4.941$. If we make $n = .030$ in the formula, this being Kutter's value for large streams, we obtain the same.

FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899 C. H. TUTTON PLATE 5.



FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899 C. H. TUTTON. PLATE 6.

To make a few comparisons:

Mr. J. C. Quintus measured the discharge of the Niagara River at this place. From his measurements are deduced $R = 22.89$, $S = .000144$, $v = 4.941$. If we make $n = .030$ in the formula, this being Kutter's value for large streams, we obtain the same.

In *Engineering News* for April 4, 1895, is given the following experiment on a 21-inch cast iron main, made in Seville, by Charles A. Friend: $R = .4375$, $S = .0015118$, $v = 2.951$. This would require $n = .0113$ in this formula, Kutter's requiring $n = .011$.

Desmond FitzGerald, in a paper read before the American Society of Civil Engineers (see their Transactions for January, 1896), records a series of very valuable experiments made on a 48-inch cast iron pipe known as the Rosemary pipe. Taking three of these experiments on the pipe after cleaning and applying the value of n as deduced from Mr. F. P. Stearns' previous experiments on the same pipe, or $n = .0108$, which we find from Trautwine and Hering's translation of Kutter is the same value as required by Kutter's formula, we find:

R.	S.	v MEASURED.	v CALCULATED.
1.0	.0000182	.539	.608
	.0005726	3.387	3.412
	.0026110	7.245	7.287

It will be seen that for the very low head this formula, like Kutter's, does not give quite such close agreement as for greater heads.

In the lately talked of Pequannock main of the East Jersey Water Company, 48 inches diameter, of lap-riveted steel, if we take the data given by Mr. Hering in *Engineering News* of January 23, 1896, $R = 1.0$, $S = .002$, $v = 4.45$, we will find $n = .0155$, which we will also find is the average value of n in Kutter's formula as deduced from Herschel's experiments on the Holyoke flume of similar construction. (See Trautwine and Hering's Kutter before referred to.)

BUT ARE ANY OF THE FOREGOING ASSUMPTIONS CORRECT?

If we desire a formula for a special purpose we find Dr. Lampe's formula for iron pipes, which may be written

$$v = 203.3\ R^{0.694}\ S^{0.555},$$

and that of William E. Foss, of the Boston Society of Civil Engineers, and given in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. XIII, for the same case, which may be written

$$v = 191\ R^{0.7272}\ S^{0.5454},$$

and Professor Osborne Reynolds' formula, given in the proceedings of the Royal Society of London for 1883, which may be written

$$v = CR^{3k-1}\ S^{k}.$$

all of which decidedly express that v does not vary either with $S^{\frac{1}{2}}$ or with $R^{\frac{1}{2}}$, unless as particular cases. Professor Reynolds' derivation also shows that k is a variable only for the particular condition of the surface of the pipe. The formula was deduced by his system of logarithmic homologues. Varying his process a little, let us now examine actual experiments, and for the present relegate theory to the background.

In Colonel Mark Beaufoy's "Nautical Experiments" (1795) is given the solution of the ordinary exponential formula, which he calls Garnett's Theorem, and applies to the discussion of his experiments on water friction. That is, if we have an equation of the form $v = S^x$, then $x = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } S - \text{Log } S^1}$.

In order to illustrate it, let us take the following four series, comprising twenty-two experiments on wooden pipes, flowing full:

Of these Nos. 1 to 5 were made in California by Hamilton Smith, Jr., on a newly-bored redwood pipe of about 1.25 inches diameter. Quantity discharged, and therefore v, was determined by direct measurement; S was determined by an engineer's level, the head being corrected for loss due to contraction at entrance of pipe.

Nos. 6 to 13 were made in France, by Messrs. Darcy & Bazin, being their Series 52, as reported in their "Recherches Hydrauliques," on a rectangular pipe of unplaned poplar plank 1.575 feet wide and .984 feet deep. Q was determined by weir measurement in these experiments, and S was determined by piezometers. Nos. 14 to 21 are by the same experimenters, on the same kind of pipe, except that it was 2.625 feet wide and 1.64 feet deep. They are reported as Series 51. Q and S were determined in the same manner as the preceding experiments.

No. 22 was made on the Moon Island conduit pipe, in Boston, by Eliot C. Clarke, and is reported in his work on Boston main drainage. It was a square pipe of planed plank, measuring 6 feet on a side. Q in this experiment was determined by pump measurement. The value of S here given may not be exact, as it is calculated inferentially from the data given in his report instead of from direct record. He records the value of C in the Chezy formula, giving R and v. It is therefore simple to find S, though the final figure of decimals may vary to a very limited extent from the truth.

In the fifth column of the table is placed the values of v as calculated by the formula about to be deduced, for comparison with value of v as obtained by actual measurement, the total difference being only about one-half of one per cent.

FLOW OF WATER IN PIPES.

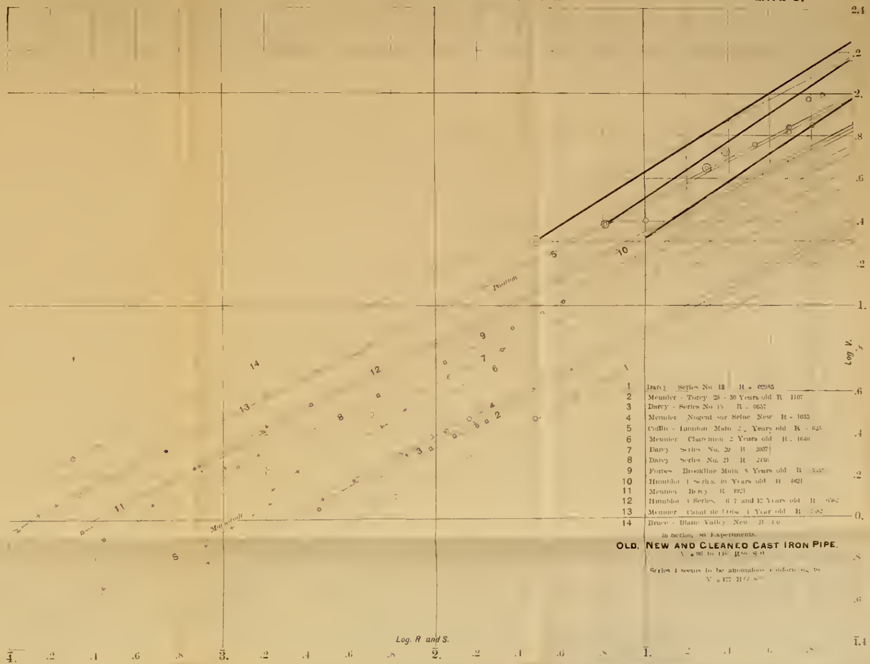
ENGINEERS SOCIETY OF WESTERN NEW YORK. C. H. TUTTON. PLATE 7.

NEW CAST IRON AND CEMENT LINED PIPES.

JOUR. ASS'N ENG SOCS., VOL. XXIII, No. 4, OCT., 1899. C. H. TUTTON—FLOW OF WATER IN PIPES.

FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. C. H. TUTTON PLATE 8.



OLD, NEW AND CLEANED CAST IRON PIPE.

In the fifth column of the table is placed the [illegible] calculated by the formula about to be deduced, for comparison with value of v as obtained by actual measurement, the total difference being only about one-half of one per cent.

EXPERIMENTS ON WOODEN PIPES.

No.	R.	S.	v MEASURED.	v CALCULATED.	ERROR %.
1.	.0263	.02419	1.653	1.752	6.
2.		.05094	2.469	2.561	4.
3.		.07610	3.008	3.142	4.6
4.		.10306	3.519	3.668	4.
5.		.13115	3.986	4.148	4.
6.	.3028	.000533	1.230	1.255	1.6
7.		.001067	1.778	1.789	0.5
8.		.001733	2.277	2.291	1.
9.		.002733	2.940	2.890	−2.
10.		.003867	3.530	3.449	−2.3
11.		.006267	4.350	4.412	1.4
12.		.007267	4.626	4.758	2.
13.		.008800	5.308	5.246	−1.
14.	.5046	.000475	1.667	1.658	−0.6
15.		.001076	2.520	2.516	
16.		.001899	3.373	3.362	
17.		.002911	4.226	4.180	−1.
18.		.004272	5.069	5.083	
19.		.005063	5.528	5.543	
20.		.005760	5.915	5.922	
21.		.006614	6.375	6.354	
22.	1.500	.0008428	4.800	4.560	−5.
Totals.			80.147	80.539	0.5

Now let us examine these experiments and see if we can find a formula which will represent the entire series, and which can be expressed in the form $v = CR^xS^y$.

Taking logarithms, $\text{Log } v = \text{Log } C + x \text{ Log } R + y \text{ Log } S$, and for the next state $\text{Log } v^1 = \text{Log } C + x \text{ Log } R + y \text{ Log } S^1$.

But R and C being constant for the same pipe, we find by subtracting the second of the above equations from the first and solving for y, $y = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } S - \text{Log } S^1}$, or Garnett's Theorem, which expression is the equation of a straight line whose co-ordinates are the logarithms of v and S respectively.

Plotting, then, these experiments by logarithmic co-ordinates, the experiments being shown in circles on the accompanying plate, No. 1, we find that parallel straight lines can be drawn through each series of experiments at the constant inclination, indicated by the above formula of $y = .51$.

Now prolong all of these lines until they intersect the axis of v. These intersections show the logarithms of the velocities at the point at which $S = 1$ for each different value of R, and where, consequently, $\text{Log } S = 0$.* Substituting this particular set of velocities for v in the original formula we will in all cases have $S = 1$, and the formula reduces to $v = CR^x$. . . . (a) Again taking logarithms, we obtain in the same manner as before

*There would be a decided flavor of the absurd in this construction if S represented only the sine of slope.

$$x = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } R - \text{Log } R^1}.$$

therefore plotting the logarithms of R, as shown in double circles in the plate in connection with these special values of v, we obtain by the corresponding line, which passes very closely through all of the points thus located, $x = .66$. That is, $v = CR^{.66} S^{.51}$. But when R becomes 1, or its logarithm = 0, equation (a) reduces to $v = C$ or $\text{Log } v = \text{Log } C$, or the logarithm of C is found at the point where the line for $R = 1$ and $S = 1$ crosses the axis of v, shown on the plate by the larger set of circles.

Reading this logarithm from the drawing, and finding the corresponding natural number, the complete equation for the case of wooden pipes becomes

$$v = 129 R^{.66} S^{.51}.$$

The results of these experiments as calculated by this formula are given in the table.

Taking these experiments *alone*, the formula $v = 140 R^{.687} S^{.52}$ will give a little closer results. The reason for adopting the form given will be seen presently.

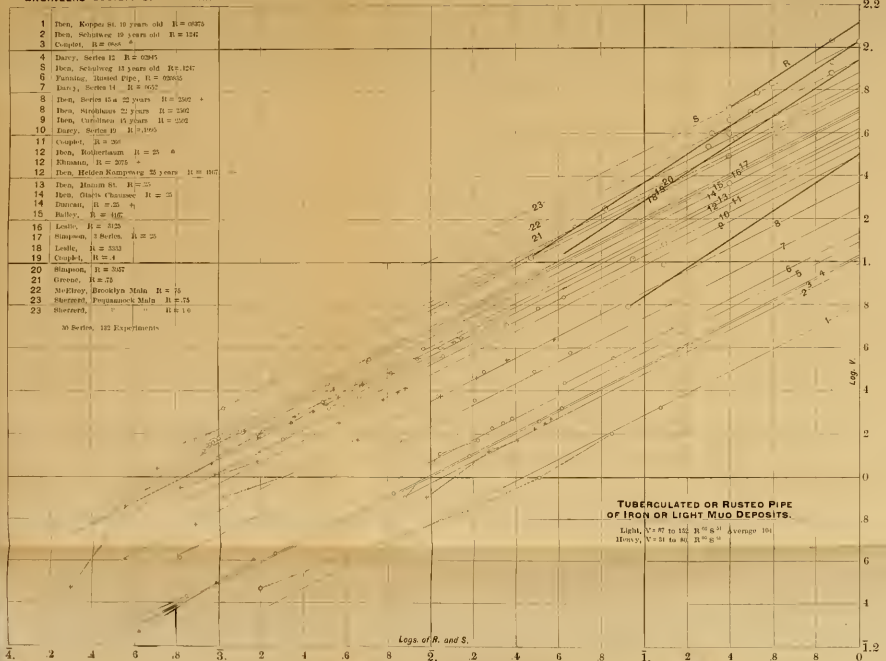
By this method the following experiments have been examined:

CLASS.	SERIES.	EXPERIMENTS.
Wooden pipe.—Smith, Darcy and Bazin, Clarke...	4	22
Tin pipe.—DuBuat, Bossut..............................	4	42
Lead Pipe.—Darcy, Iben, Bossut, Provis, Leslie, Jardine, Couplet, Neville, Hodson................	11	79
Glass pipe.—Darcy, Smith....................	5	32
New wrought iron and asphalt coated pipe.—Darcy, Smith, Couplet, Crozet, Tubbs, Rowland, Iben, Gale, Ehmann, Lampe, FitzGerald.................	37	216
Coal-tarred, galvanized and lap-riveted pipe.—Iben, Ehmann, Brush, Herschel..................	11	86
New cast iron and cement-lined pipe.—Darcy, Ehmann, Iben, Russell, Fanning, Friend, Woods, Stearns, Meunier, Bruce..................	17	103
Old cast iron pipes (cleaned).—Darcy..................	4	30
Lightly tuberculated, rusted or with slight mud deposits.—Darcy, Couplet, Iben, Ehmann, Duncan, Simpson, Leslie, Greene, McElroy, Meunier, Humblot, FitzGerald, Bailey, Sherrerd, Forbes, Coffin....................................	32	142
Heavily tuberculated.—Couplet, Iben, Fanning...	9	49
Uncertain classification, but supposed earthenware.—Murray, Bidder..................................	6	8
Rejected.—Darrach	6	53
Brick conduits.—Tracy, Clarke, Elliott, McElroy, Artingstall and unknown author...........	7	38
Total.—12 classes, reported by 44 authors...	153	900

Upwards of one thousand experiments have been examined since, with very gratifying results.

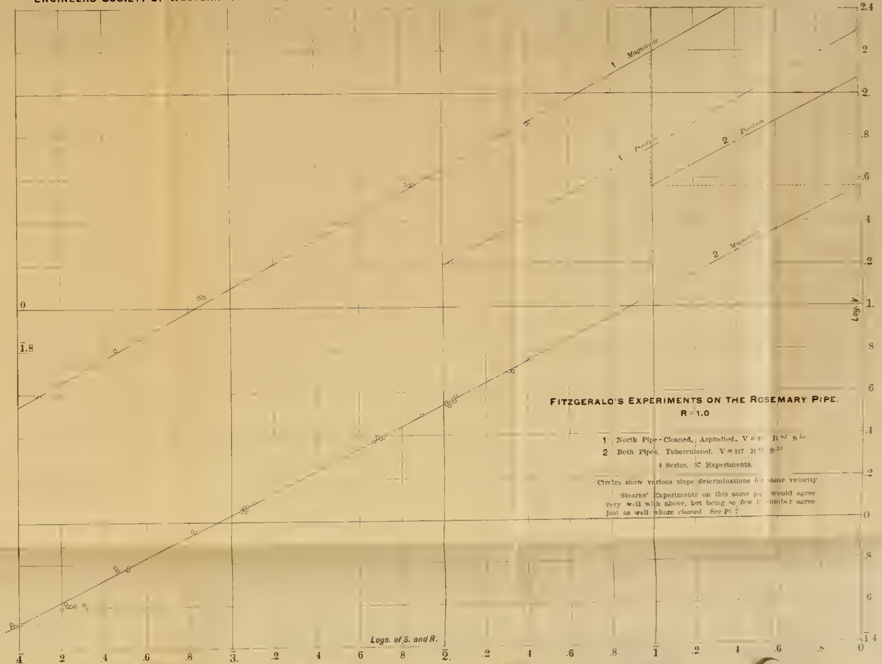
FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898 C. H. TUTTON. PLATE 9.



FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898 C. H. TUTTON. PLATE 10.



Log v — Log v[1]

The Darrach series were rejected, as they seem to be interpolations and not experiments; the value of v increasing in an arithmetical progression with that of S, which is a result manifestly impossible and directly opposed to the results obtained from the other 147 series and 847 experiments. Plate 3 also clearly shows the impossibility. (On referring to the original paper they will be found given as "deduced tables." They cannot, therefore, be classed as experiments.) The Murray series are also of little value, having been, in part at least, misquoted by Mr. Murray.

These plottings cover diameters from half an inch to 8 and 12 feet, velocities from 0.1 to 48 feet per second, values of S from .0000095 to 10.7419 and lengths from 20 feet to 20 miles.

DeVolson Wood, in Vol. VII of the Transactions of the American Society of Civil Engineers, says about hydraulic engineers that "there is a peculiar satisfaction to them in discarding all that has been done before and finding fault with all their predecessors, and especially with those who have written on the subject." Disclaiming such intent, it must be said, with reference to one eminent scholar who sweepingly condemns the experiments of Iben, Ehmann, Provis, Leslie and others, that had he examined their experiments in this light he would have found very striking confirmation of the general law, many of them equal, and some superior, to his own. While no series of actual experiments have been found worthless, single experiments have been found difficult to analyze until obtaining a consecutive series of the same class from which the law of the exponents could be deduced.

Proceeding in this manner with the different classes, and as shown on the plates in detail, the following table is found for the values of x and y in the formula $v = CR^x S^y$, in which formula, speaking generally, n is a coefficient of rugosity dependent on the mechanical condition of the pipe, and x is a constant of adhesion depending on the physical constitution of the pipe; for example, x for cast iron remains constant at .66, but n varies according to its roughness.

CLASS.	x.	y.
For wooden pipes and cast iron pipes, either new, old, lightly or heavily tuberculated, or cleaned.	.66	.51
For new wrought iron or asphalt-coated pipes........	.62	.55
For tarred, galvanized or lap-riveted pipes...........	.69	.48
For tin, lead and zinc pipes..................................	.59	.58
For glass and brass pipes.....................................	.61	.56
Large brick conduits.....	.65	.52

One peculiarity of these exponents immediately appears. In every case their sum is constant and equal in every case to x + y

$= 1.17$, whence the formula can be written $v = CR^{1.17-m} S^m$. (If desired, this can readily be expressed in the simple form $S = C^1Q^k$, C^1 being a constant varying with diameter and with m, a form adopted by Foss, Flamant and others.) It will be observed that Professor Reynolds finds the sum of the exponents of v and R constant and equal to 3.

If, then, we make the assumption $m = \frac{1}{2}$, we immediately obtain the formula previously deduced theoretically, or

$$v = CR^{2/3} S^{1/2}.$$

It is therefore claimed that for a single general expression involving the above assumption this formula is of as wide applicability as any yet presented.

Next as to the value of the coefficients C.

For wooden pipes there is a gratifying uniformity in the value $C = 129$.*

For tin pipes the same uniformity is found for $C = 192$.

For lead pipes the older experimenters are unanimous on $C = 189$, while the later ones are just as unanimous on $C = 168$.

For glass pipe $C = 169$ holds in all but a single series, which drops to $C = 141$.

In asphalt-coated pipes the largest number of series tend to $C = 170$, although some fall as low as $C = 140$, and FitzGerald's experiments on the cleaned Rosemary pipe rises to $C = 199$. (Incidentally, the sum of the total experimental values of v on the cleaned Rosemary pipe is 63.631 feet. Calculated by the formula $v = 199 R^{.62} S^{.55}$, they would be 63.643 feet, with a maximum error in any one experiment of about 5 per cent.)

For new wrought iron pipe C varies between 127 to 165, with the higher figure predominating.

For galvanized pipe one series only is available, giving $C = 166$. This value cannot, therefore, be considered firmly established.

†For lap-riveted pipes, as in Herschel's Holyoke flume, $C = 79$. (The Holyoke pipe sections were about $4\frac{1}{2}$ feet long. The Pequannock main sections are about 7 feet long. We could infer, therefore, 10 per cent. greater discharge or greater value of C for this, or say $C = 87$, which would conform to the single experiment given by Mr. Hering. It is, however, stated that the joints were found covered with algae. This might have the effect of throwing it into the lightly tuberculated pipe class, or $v = 105 R^{.66} S^{.51}$. The single

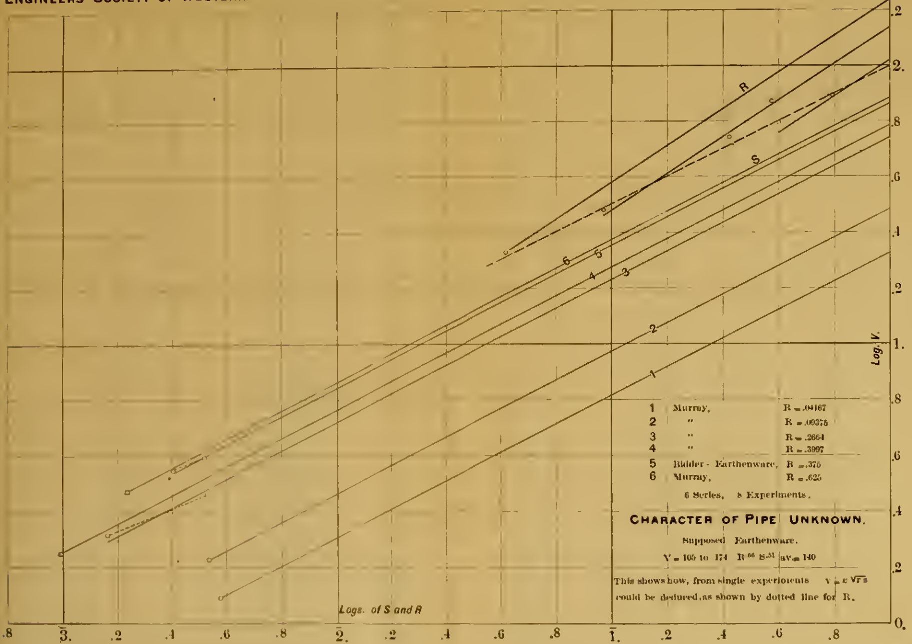
---

*Since this was written several experiments on wood stave pipe have been received, indicating a value for C of about 155 in the same formula. The experiments of Marx, Hoskins and Wing would seem to indicate a value of .58 for the exponent of S, but we would not yet advise its adoption, although the difference may possibly be due to the difference in square and round sections.

†See note at end of paper.

FLOW OF WATER IN PIPES.

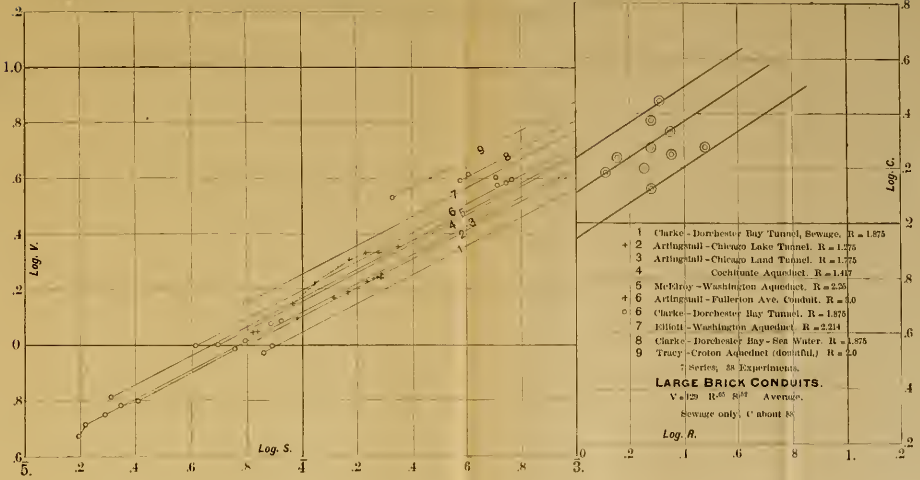
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C H TUTTON PLATE 11.



JOUR. ASS'N ENG. SOCS., VOL. XXIII, No. 4, OCT., 1899. C. H. TUTTON—FLOW OF WATER IN PIPES.

FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C. H. TUTTON. PLATE 12.



*Since this was written several experiments on wood stave pipe have been received, indicating a value for C of about 155 in the same formula. The experiments of Marx, Hoskins and Wing would seem to indicate a value of .58 for the exponent of S, but we would not yet advise its adoption, although the difference may possibly be due to the difference in square and round sections.

†See note at end of paper.

record given is deemed insufficient to properly classify it, owing to the peculiar nature of the obstruction.)

Mr. Morris R. Sherrerd, engineer of the Newark Water Department, has kindly furnished me with data confirming Mr. Hering's figures, and also relative to a 36-inch main of similar construction. While difficult to place these from single experiments, they tend to show that all iron pipe, of whatever nature, tend to the value $v = CR^{.66} S^{.51}$ after a few years of service. The 36-inch main would require $C = 129$ in this form, being four years old.

*Tarred pipes run very evenly, the value of C varying from 115 to 152, with no particular choice. It should be placed at about 120 for general use. The plate submitted, No. 6, also shows that the low coefficient in this formula of $C = 100$ for Iben's "Uhlenhorst" experiments is probably *not* due to some unknown obstruction, as reported, but is entirely due to the nature of the coating.

New cast iron, old cast iron cleaned and cement-lined pipes vary from $C = 126$ to $C = 158$, being very evenly distributed between these values, irrespective of radii. Benzenberg finds 129 for 60-inch pipe.

For iron slightly tuberculated, or with light mud deposits, C ranges from 87 to 132, the majority clustering around 105 as an average value, although the Rosemary pipe shows 117. (FitzGerald's series.)

Heavily tuberculated pipe ranges anywhere from $C = 30$ to $C = 85$. There is nothing to indicate any preference, as in the nature of the case there cannot be.

In large brick conduits C has the value 129 when unobstructed. As many of the experiments in my possession on these were made on conduits obstructed by numerous shafts, they are not fairly comparable with unobstructed pipe. For instance, in the obstructed Fullerton avenue conduit of the Chicago Water Supply $C = 91$; for the obstructed Chicago Land Tunnel $C = 110$, while for the unobstructed Lake Tunnel and the Washington Aqueduct it reaches 129, which is also found by Gaillard's experiments.

The history of an asphalt-coated pipe might be written thus:

New	$v=175\ R^{.62}\ S^{.55}$
1 year old (or when growing slimy)	$v=140\ R^{.66}\ S^{.51}$
4 years old (very light tuberculations)	$v=132\ R^{.66}\ S^{.51}$
6 years old	$v=124\ R^{.66}\ S^{.51}$
8 years old (light tuberculations)	$v=116\ R^{.66}\ S^{.51}$
10 years old (average of distribution pipes)	$v=108\ R^{.66}\ S^{.51}$
14 years old } (varying with amount of tuberculation)	$v=100\ R^{.66}\ S^{.51}$
18 years old } (varying with amount of tuberculation)	$v=\ 90\ R^{.66}\ S^{.51}$
25 years old (heavily tuberculated)	$v=\ 80\ R^{.66}\ S^{.51}$ or less.
	Any of these constants may vary according to the character of the water in hastening or delaying tuberculation.

*See note at end of paper.

In all of these experiments the total head has been reduced by the loss of head, due to contraction at entrance, where not measured by piezometers, by the formula $h' = \frac{v^2}{2go^2}$, o being the coefficient of contraction.

Some of the varying values of C could no doubt be more closely harmonized should we take into account the varying temperature of the water, as did Professor Reynolds, who found that by making a rectangular shift of the lines representing the relative values of v and S through horizontal distances represented by the difference of the logarithms of $\frac{D^3}{P^2}$ for any two pipes, and vertical distances represented by the difference of the logarithms of $\frac{D}{P}$ in which D is the diameter of the pipe and P a coefficient of viscosity depending on the temperature of the water, that better harmony could be obtained. This consideration has been neglected as a refinement unnecessary for the purposes of the present paper.

It is also possible that closer results might have been obtained for some of the cases had a third place of decimals been considered in the values of the exponents.

Every value of C, x and y here given has been obtained directly from the drawings submitted.

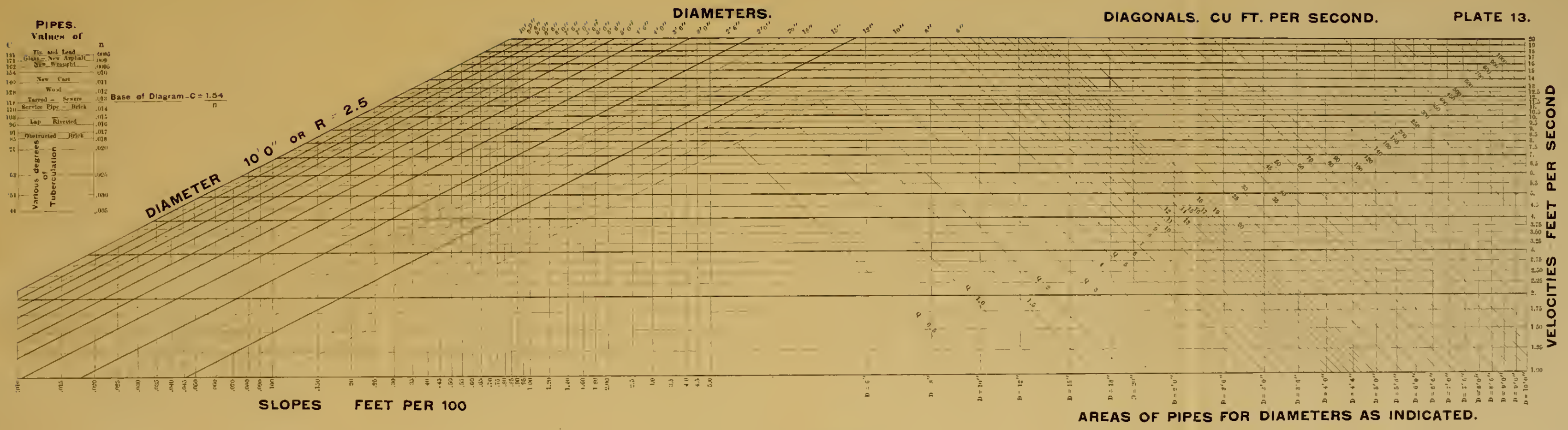
The graphical solution of the inverse problem, it will be seen, presents a far less complicated diagram than Kutter's. The process is as follows: Having assumed a value of C, plot its logarithm on the axis of ordinates, and draw an indefinite line on the slope x. If using any particular value of R, at the point where this line crosses the logarithm of R on the axis parallel to that of the abscissæ, draw a horizontal line back to the axis of ordinates, and from this point draw an indefinite line on the slope y. The logarithmic co-ordinates of any point on this line are the logarithms of corresponding values of S and v. That is, three straight lines and a table of logarithms solve the question with all its complications, or these lines may be directly marked with the corresponding natural numbers.

Other simple modifications will readily suggest themselves, as if total friction head for a given length of pipe is wanted, a line drawn parallel to the line last found and at a distance from it equal to the logarithm of the pipe length, measured on the axis of x, will pass through the logarithms of all friction heads corresponding to various velocities. The sewer diagram shows how to include total discharge in cubic feet per second, and how to use all values of n, R, S, v or Q from one plotting.

The original intention in this paper was to take up the subject of open channels also, including in this pipes flowing partially full,

SEWER DIAGRAM.

$$V. = 118\, R^{2/3} S^{1/2}$$



FLOW OF WATER.

This diagram is based on n =.013, the value for sewers.

Example:— A 3 ft. sewer laid on a grade of .25 per 100, has a velocity of 5.0 per second, and carries 35 cubic feet of water when running full.

To dispose of 300 cubic feet of water per second with a 6'-6" sewer, it must have a velocity of 9 feet per second, which requires a grade of 0.30 per 100 feet, or an 8 foot sewer on a grade of 0.10 per 100 and velocity of 6.0 will do it.

To change value of n and use same diagram.

From table "values of n," take in a pair of spacers or on a slip of paper the distance from line "Base of Diagram" to value of n desired. Lay this distance off up or down on the slope lines, (verticals), from the intersection of the line of Diameter (inclined), and use the velocity thus indicated (horizontals) as the proper velocity. Tracing this velocity through to the vertical "D" on right of diagram, it intersects this vertical on the inclined line Q, showing quantity discharged

A vertical drawn from the foot of any "Q" line corresponds to an *area* in square feet equal to the number of *cubic* feet represented by the "Q" line, and this vertical will intersect any velocity line on a new "Q" line corresponding to the quantity of discharge for that area and velocity, hence by marking R instead of D on the inclined lines on left of diagram, this will include all cases of open Channels within its limits

The diagram covers—Diameters from 6" to 10 feet or R from .125 to 2.5, velocities from 1 to 20 feet, slopes from .0001 to .05, discharges from 0 5 to 1000 cubic feet.

C. H. TUTTON, 1896.

the l
by p
cont

harr
the
recta
and
the l

sent
dian
the t
This
for t

for s
in th

from

pres
is as
the a
using
the l
a ho
draw
of ar
of S
solve
direc

if to
draw
to th
pass
vario
disch
n, R,

The original intention in this paper was to take up the subject of open channels also, including in this pipes flowing partially full,

as sewers and water conduits, but, as it has already reached a sufficient length, that will be reserved for a future communication. It may, however be briefly stated regarding open channels that the formula $v = \frac{1.54}{n} R^{2/3} S^{1/2}$ will apply as long as we can consider the flow uniform and surface parallel to bottom inclination, but it will not correctly apply to rapidly rising or falling rivers or to those discharging against tidal action, on which conditions Kutter's formula is, unfortunately, principally based.

NOTE.—The experiments of Rowland on high heads were taken from Trautwine's "Kutter," but there is reason to believe them incorrect, owing to an error in reduction in the original paper in Vol. XIX, Trans. A. S. C. E. The error, however, does not affect their classification.

It is stated in the text that for tarred and lap-riveted pipes $x = .69$, $y = .48$. We have allowed this to remain as in the original to avoid new plates, but would state that a much larger field of investigations indicates $x = .66$, $y = .51$.

For tarred pipe C should have about the same value as for cast iron pipe of the same age, while for lap-riveted pipe it decreases from about 125 or 135 for new pipe to 110 or 114 for pipe "in service." The author regrets that his occupation at present is such as to prevent his giving a more complete paper, including many later experiments, which are not even referred to in the preceding, as in the following list of experiments examined since the original paper was written:

Wood pipe.—Adams, Hardesty, Henny, Marx, Wing and Hoskins.

Lead pipe.—Reynolds, Rennie, Duncan, Robison, Belidor.

Zinc pipe.—Weisbach.

Brass pipe.—Weisbach, Mair.

Rubber hose.—Fanning, Ellis, Francis, Freeman.

Earthenware.—Kuichling, Bidder.

Wrought iron.—Ketchum, Thrupp.

Cast iron, coated.—Weston.

Cast iron, tarred.—Benzenberg, Pearsons, Vodicka, Kuichling.

Old cast iron.—Robison, Chapman, Rafter, Duane, Brackett.

Lap-riveted.—Schussler, Hardesty, Herschel, Rafter, Hawks, Adams, I. W. Smith, Kuichling, Tournadre, FitzGerald, Marx, Hoskins and Wing.

Brick conduits.—Benzenberg, Gaillard, Pasini, Gioppi, Croton.

Linen and leather hose.—Freeman.

Cement-lined.—Bazin, Dumont.

THE DESIGN AND CONSTRUCTION OF A MODERN CENTRAL LIGHTING STATION.*

By H. H. Humphrey, Member Engineers' Club of St. Louis.

[Read before the Club, October 18, 1899.†]

The Keyes ordinance (No. 18,680), passed by the Municipal Assembly of the city of St. Louis, Mo., in the fall of 1896, threw open the doors to all applicants for underground conduit rights. Fourteen companies appeared at the first hearing before the Board of Public Improvements and made formal application for space for electric wires beneath the surface of the streets.

Among the applicants were several newly-organized companies, and one of them has since constructed its plant. The Imperial Electric Light, Heat and Power Company first turned current into its underground system one year ago, October 15, 1898, and has been in continuous and successful operation since that date. This paper is a discussion of the design and construction of this plant, which embodies many interesting features.

After engaging engineers, the first question that confronted the company was the selection of the system of distribution.

This plant was intended primarily to compete for business in the down-town or underground district of St. Louis, which is bounded by Spruce street on the south, Wash street on the north, the Mississippi River on the east and Twenty-second street on the west. It was required, however, that the system adopted should be capable of being extended beyond this district, and, if necessary, of covering almost the entire city. The success of the three-wire direct-current low-tension underground system in this and other countries naturally influenced the engineers in its favor. On the other hand, the cost of copper for such a system, while not strictly prohibitive, is still so large as to demand most serious study.

The class of service to be supplied had great weight in the final decision regarding the system. This service consists largely of 500-volt direct-current motors, there being also some 220-volt motors of smaller size. Another important part of the service was to be arc lighting. The growing popularity of the inclosed arc lamp indicated that this field would be very profitable. The fur-

*The engravings for the photographic illustrations of this paper have been prepared without expense to the Association.—Secretary, Ass'n of Eng. Socs.

†Manuscript received October 25, 1899.—Secretary, Ass'n of Eng. Socs.

nishing of incandescent light was by no means of secondary importance.

In order to reduce the first cost of station equipment and underground work, both conduits and cables, it was deemed advisable that all three kinds of service should, if possible, be supplied from one generator, delivering its output through one underground duct and one service cable.

These considerations led to the adoption of a three-wire direct-current system of distribution, differing in important details, however, from the methods heretofore employed. 220-volt incandescent and 220-volt arc lamps were both to be used on the sides of the three-wire system, while 500-volt motors would be connected directly across the outside wires. The saving in copper over the usual 110-220-volt system, based upon the same percentage of drop, is three-fourths. Furthermore, the area which can be supplied from one central station at the same percentage of loss is increased sixteen times. If in the 110-220-volt system the limit with a certain drop be placed at one mile from the station in all directions, an area of 3.14 square miles can be covered. With the 220-440-volt system the distance reached from the station in all directions is four miles, covering an area of 50.24 square miles. By the proper use of boosters with storage batteries at the ends of feeders, such a system may be extended over a district within a radius of 10 miles from power plant.

The next question in point of importance was the location of the plant. It would be natural to assume that such a plant should preferably be located upon the river front in order to secure cheap water, and upon a railway switch to secure cheap fuel. In this case, however, no suitable property was available on the water front. Furthermore, fuel coming from the Southern Illinois district can be delivered by wagon from East St. Louis almost as cheaply as when bridge and switching charges are paid on carload lots unloaded at the plant. Very few St. Louis power plants are located upon railway switches, and one large plant which is so located is supplied with coal hauled in wagons from East St. Louis. Under these circumstances the plant should be placed as near the electrical center as possible. A suitable lot was found at the southeast corner of Tenth and St. Charles streets, and the plant was located there.

The designing of a plant which would ultimately utilize to the best advantage all the limited space available was next undertaken. Before entering upon the details of this work, however, one of the engineers spent some time on an extended trip through the East,

visiting the large power plants in New York city, Boston, Pittsburg, Philadelphia, Buffalo and Chicago, making a study of the most modern plants in these cities. After much study it was decided to locate the boilers, dynamos and engines all upon the street level, rather than place part of the apparatus below street level, as is frequently done. A study of many different designs led to the division of the plant longitudinally, east and west, into an engine room and a boiler room, each extending the full length of the property; this plan giving an ultimate capacity of 10,000 horse power.

Hypothetical load curves were next prepared, covering the service expected from this plant, including incandescent and arc lights

Fig. 1. Exterior View of Station.

and motor service. The three were then combined into one curve representing the entire anticipated output of the plant under the heaviest service of the winter months. (See Fig. 13.) A study of this curve indicated that the number of units in the plant should be at least five. This number fitted both the minimum load, which was about one-fifth of the maximum, and provided admirably for reserve. In case of accident during the peak of the load, the other four units could take the place of the disabled one by each carrying 25 per cent. above its rating. In case of the adoption of a storage battery

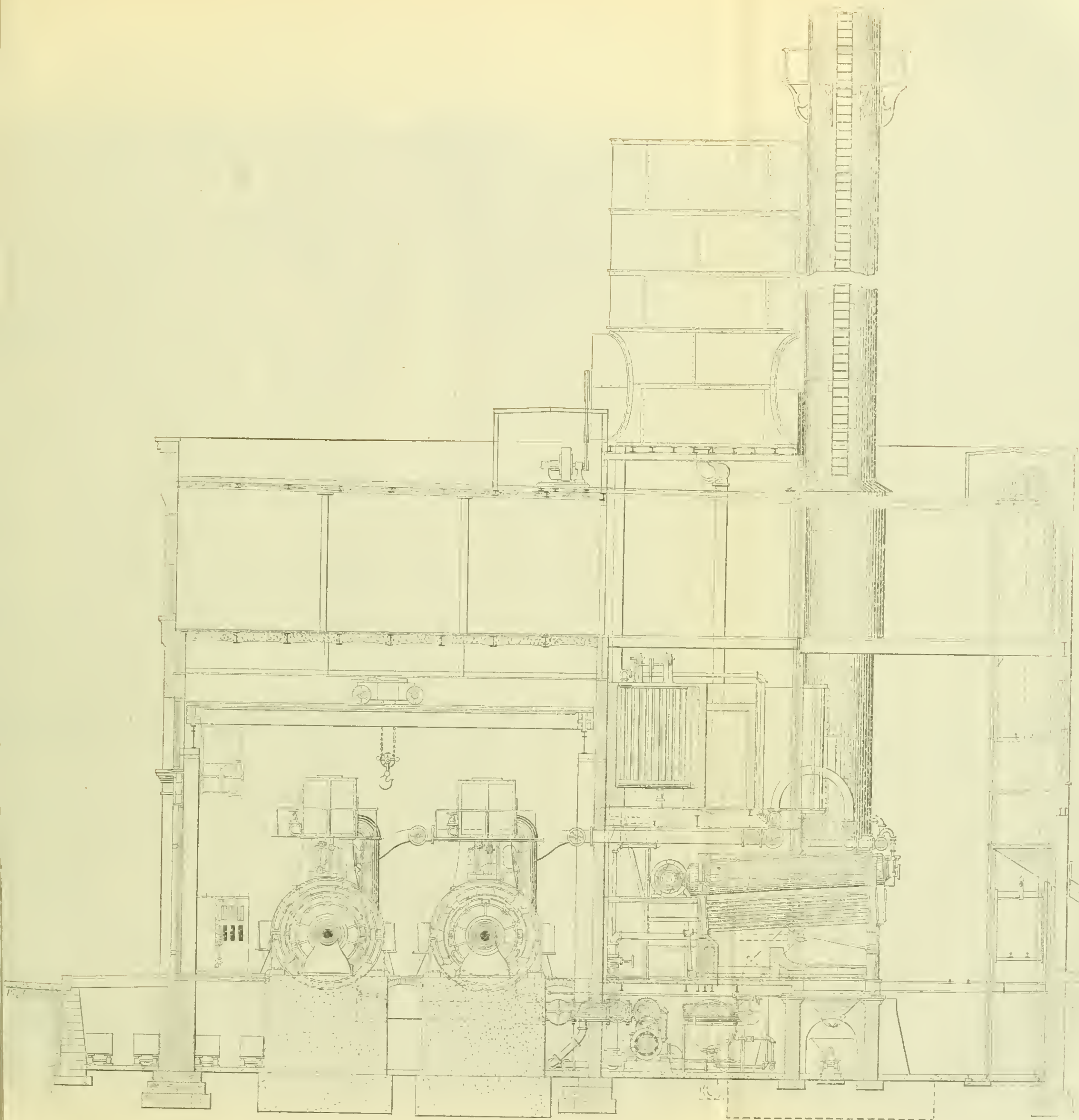


Fig. 2. Cross Section of Plant.

sufficiently large to carry the reduced load during the latter part of the night, and assist the generators during the times of maximum load, it was deemed safe to reduce the number of units to three, the battery to be of the same capacity as each of the units.

In designing steam plant it was necessary to determine beforehand what economical auxiliary apparatus, if any, should be installed in connection therewith, as all of these affect the capacity of the boiler plant. The rule adopted by the engineers in determining whether any species of economical apparatus was worth installing was that it should be able to earn, under a conservative estimate of the conditions of service, and taking into consideration the low price of fuel in this territory, 18 per cent. annually upon its first cost.

Applying this rule to the consideration of compound versus simple engines resulted in favor of the compound engine. A further comparison between compound non-condensing and compound condensing engines showed the ultimate economy to be in favor of the condensing type. Economy in the use of water, which is obtained from the city's mains at considerable expense, necessitated the installation of a cooling tower in connection with the condensing plant.

The application of the above rule to the question of fuel economizers showed that they would be a good investment.

It was decided to use water tube boilers, as this type gives large capacity in small space, is absolutely safe, quick steaming, economical in fuel and can be had in large units. With good draft they may be overworked 50 per cent., and under mechanical draft they may be operated for short periods at double their rating. Down draft furnaces, of the type which has proven so successful in St. Louis, were selected. They are capable of burning low grade coal, running high in moisture and clinker, and may be overworked far beyond the rating of the boilers. They are also simple, easily repaired and not likely to get out of order. The most important characteristic, however, is that they are smokeless, thus complying with the city ordinances. They improve the fuel economy, and add somewhat to the boiler's capacity.

It was decided at the outset to divide the total chimney capacity into two units, for the reason that the draft would be better at light loads, and one stack only needed to be built then, as but a part of the plant was to be installed to start with.

On account of the use of the 220-440-volt system of distribution and the many economical features of the steam plant, this station has attracted unusual attention. A detailed description of

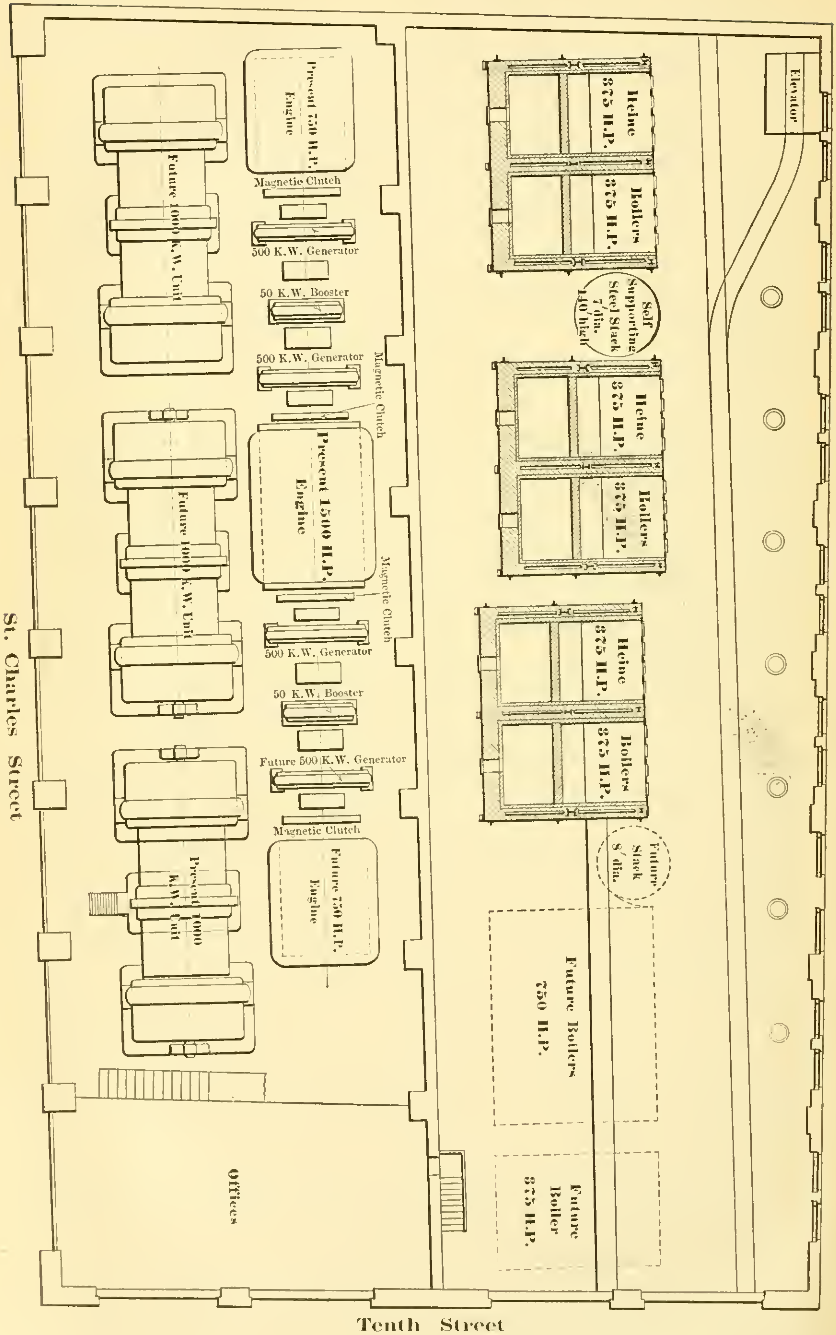


Fig. 3. Floor Plan of Boiler and Engine Room.

the apparatus used therein may therefore have more than passing interest.

BUILDING.

The plant is located at the southeast corner of Tenth and St. Charles streets, on a lot having a frontage of 142 feet 6 inches on St. Charles street by 85 feet $2\frac{1}{2}$ inches on Tenth street and 92 feet $3\frac{1}{8}$ inches on the east line. An exterior view of the building is shown in Fig. 1. Fig. 2 gives a sectional view of building, and Fig. 3 a plan of the engine and dynamo room.

The building is of dark red brick, three stories high above the basement and of same dimensions as the lot above street level. The area under sidewalks on both Tenth and St. Charles streets is excavated to the curb line, which forms the outer line of retaining wall. The second story is omitted everywhere except over the main office, thus giving a clear height in the engine and boiler rooms of 30 feet. The third story, which is 15 feet high, is devoted to store rooms, testing department, etc. The floor of the third story over the engine room is carried on steel girders, resting upon the division wall and on brick piers on the St. Charles street side of the building. The floor over boiler room is supported on I beams resting on steel columns in front of the boilers, and upon the division wall and the outside wall of building on the alley side. The entire structure is fireproof. All floors are of cinder concrete carried on corrugated iron arches sprung between I beams. The roof of book tile with composition gravel covering. Engine and boiler rooms extend the entire length of the building, and are separated by a division wall having fire doors at all openings. Beneath the engine room are the storage batteries, extending partly under the sidewalk. Beneath the boiler room is space for coal storage, ash handling and the location of condensing apparatus and piping. The floor of engine room is laid with hexagonal tile, and the walls for 6 feet above the floor are wainscoted with marble. The main offices of the company occupy the Tenth and St. Charles street corner on the first floor. The private offices are in the second story, directly above. An elevator at east end of the boiler room runs from basement to third floor.

BOILERS.

There are four Heine boilers, Fig. 4, arranged in batteries of two each, with one stack between them, and economizers in the rear of and above the boilers. Each boiler contains 171 $3\frac{1}{2}$-inch water tubes 16 feet long. The total square feet of heating surface of the four boilers is 10,872. Each boiler has a rated capacity of

11,250 pounds of water per hour with feed water from the economizers at 200° F., into dry steam of 175 pounds pressure above atmosphere, and is guaranteed to be capable of developing continuously one-third more. Efficiency guarantee is 70 per cent. of the calorific value of the coal at any load between rating and 20 per cent. above. This is equivalent to evaporating 7.21 pounds of water per pound of Mount Olive nut coal of 10,600 B. T. U. The boilers are designed for a working pressure of 175 pounds per square inch, and tested under a hydrostatic pressure of 250 pounds. The

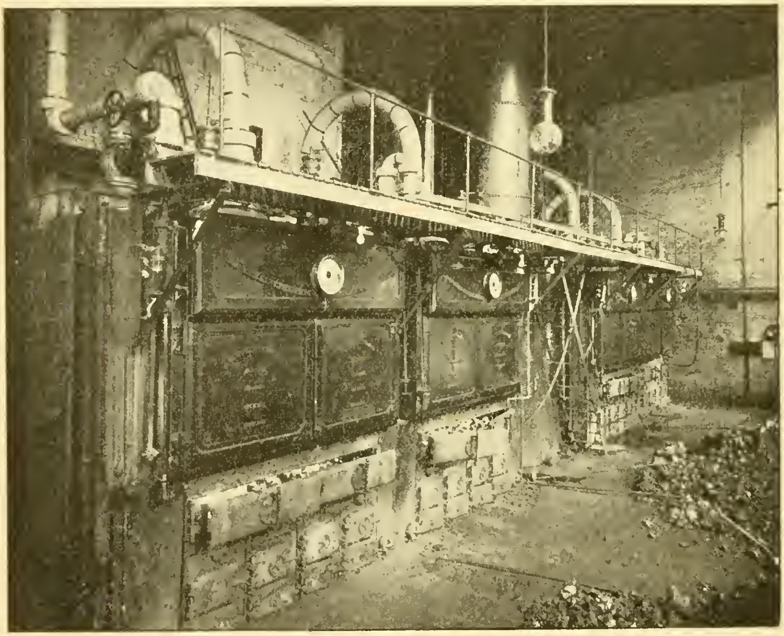


Fig. 4. Front View of Boilers.

entrainment is guaranteed to be less than 1 per cent at rating, and not more than $1\frac{1}{2}$ per cent. at one-third above rating. Each boiler is equipped with the down draft furnace. A feature of these furnaces which is original with the engineers is making the fire doors open the full width of the furnace, greatly facilitating inspection and care of the fires. Two additional Heine boilers of the same capacity are now being installed.

CHIMNEY.

The present boilers are served by one steel stack, Fig. 5, 7 feet inside diameter, 140 feet high above street level. The design of the complete plant provides for another 7-foot or 8-foot stack for

the additional boilers, which are to go in. The lower 10 feet of the present stack are made of $\frac{1}{2}$-inch steel plates; the next 20 feet of $\frac{3}{8}$-inch plates; the next 25 feet of $\frac{5}{16}$-inch plates, and the next 85 feet of $\frac{1}{4}$-inch plates. It is self-supporting and unlined. There is a ladder extending up from the roof of the building, and an ornamental platform surrounding the top. The base is supported upon and rigidly bolted to a massive brick foundation 14 feet deep, and which is solid except for the ash car passage which extends through it. The stack is provided at the base with suitable door for cleaning. Through the third story of the building it is surrounded by a sheet steel casing which provides ventilation for the boiler room. There is an improved draft gauge by which the draft can be read to thousandths of an inch at eight different points, including ash pits of four boilers, two breechings, inlet to draft fan and base of stack.

MECHANICAL DRAFT.

In order to counteract the effect of the economizers in cooling the gases from the boilers, and to permit crowding when necessary, a mechanical draft system was installed. It is of the induced type, the fan being placed directly behind the stack and between the two batteries of boilers. The bearings of the fan are self-lubricating and water cooled. This fan is driven by means of a direct-geared electric motor, designed to be operated at different speeds on either the 235- or 470-volt circuit. This motor is to be controlled automatically, so as to maintain the steam pressure practically constant, the regulator slowing down the motor as the steam pressure rises and increasing its speed as the pressure falls. The capacity of the fan is sufficient to handle the waste gases from four boilers and furnish a draft equal to 1 inch of water where the gases leave the boilers. It is capable of being speeded in emergencies sufficiently to give a draft of $1\frac{1}{2}$ inches on all four boilers.

FUEL ECONOMIZERS.

There are two Green fuel economizers, each consisting of 320 pipes, the combined heating surface being 7680 square feet. The economizer plant is capable of heating regularly and continuously 45,000 pounds of water per hour 100° F. when receiving the water at 110° F., and with the temperature of the escaping gases leaving the boilers at not less than 450° F. One-third more water may be passed through in case of necessity, but of course with diminished economy. These economizers are designed for a working pressure of 200 pounds per square inch, and were submitted to a hydrostatic test of 300 pounds after erection in position. They are provided

with automatic scrapers operated by electric motors. The economizer plant is provided with pop safety valves, necessary deflectors, soot scrapers, doors, dampers, etc. They have pressure gauges at feed water inlet, also feed water thermometers located one in pipe at entrance to economizers and one in pipe where water leaves the

FIG. 5. ROOF OF PLANT, SHOWING CHIMNEY AND COOLING TOWER.

same; also two gas flue thermometers reading to 1000° F. in smoke flue; one where gases enter economizers, and one where they leave. The necessary dampers are provided for sending the gases from the boilers either past the economizers and directly out the smokestack

or through the economizers and then up the stack, or through the economizers to mechanical draft fan and thence up the stack. The economizers as shown on the plans are located in the rear and above the boilers, supported upon a substantial iron framework and bricked in air-tight by 8-inch walls.

COAL AND ASH-HANDLING MACHINERY.

The coal and ash-handling plant is of simple and economical design, and consists of a system of cars, tracks, elevator and overhead ash bin. The cinders and ashes from the lower grates drop directly into a metallic ash hopper under each boiler. Running east and west immediately under these hoppers there is a narrow-gauge track. The ashes are dumped from these hoppers into small cars and pushed by hand along the track to an elevator, on which they are carried up and dumped into an overhead ash bin, from which they run by gravity into the wagons in the alley. Any ashes which accumulate in the stacks may be emptied directly in the cars in the same manner.

The entire space in front of the boilers in the basement is reserved for coal storage, the fuel being dumped through openings in boiler room floor. It is taken from this storage room in the same cars, tracks being provided the entire length of the coal storage space. It is then hoisted on the elevator to the floor above and distributed on tracks over the entire length of the boiler room in front of the boilers.

STEAM ENGINES.

There are now in operation two engines, Fig. 6, of the Williams vertical two-cylinder cross compound condensing automatic cut-off pattern, built by Wm. Tod & Co., of Youngstown, Ohio, and designed for direct connection to the dynamos and shafting. The east engine, No. 1, is of 750 indicated horse power, and is designed for driving one 500-kw. generator at the most economical rating of the engine when operated at a speed of 150 revolutions per minute, and supplied with steam at 170 pounds initial pressure per square inch at the throttle valve, and exhausting into a 24-inch vacuum. Engine No. 2 has double the capacity, and is similar in design to No. 1. The heavy fly-wheels are located between the A frames supporting the high and low-pressure cylinders. Each engine is so constructed as to be capable of operating continuously at double its rated capacity, and for short intervals only at one-third above its double rated capacity. This additional capacity is obtained by admitting live steam into the receiver or low-pressure cylinder. The high-pressure cylinders are steam-jacketed on the

barrel, and both cylinders on both top and bottom heads. The receiver is provided with reheating coils of copper. The main bearings are adjustable, and are provided with water jackets. The guides are water-jacketed on the running side. The cylinders and all bearings are lubricated by the Siegrist lubricating apparatus, which delivers the two kinds of oil to the cups under pressure automatically maintained by duplicate steam pumps. They also have hand oil pumps for additional safety. The cylinders have flat multiported valves driven directly from the eccentrics. The clearance is guaranteed not to exceed 6 per cent. in either cylinder. These engines are provided with shaft governors operating upon

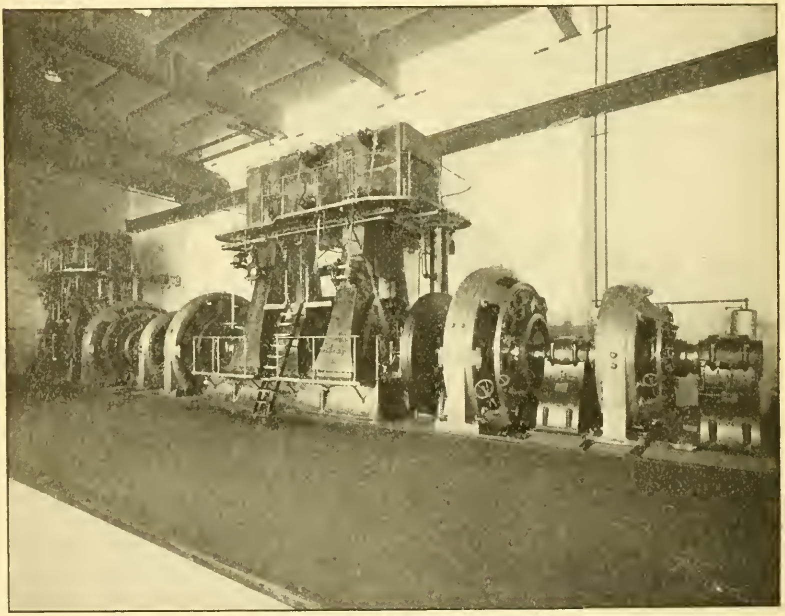


Fig. 6. Engines, Dynamos, Booster, Magnetic Clutches and Crane.

the valves of the high-pressure cylinders, and capable of varying the cut-off from 70 per cent. of the stroke back to minus $\frac{3}{16}$-inch opening. The regulation guarantees are that the drop in speed with a constant steam pressure from no load to one-third above rated load will not exceed $2\frac{1}{2}$ per cent. This guarantee also covers a variation of steam pressure between 160 and 175 pounds with constant load. The variation of speed will not exceed $3\frac{1}{2}$ per cent. with the combined changes in load and steam pressure above specified, either with or without the vacuum. The governor is also fitted with a special speeding device by means of which the engine

may be brought to the same rate of speed under friction only as under full load. When running with about 170 pounds pressure at the throttle, at 150 revolutions per minute and under a constant load at their rated capacity, the engines are guaranteed not to consume more than 15 pounds of water per indicated horse power hour.

Their principal dimensions: Engine No. 1—cylinders 18 inches and 40 inches x 30 inches; diameter steam pipe, 8 inches; exhaust, 15 inches; diameter crank shaft, 12 inches; length of bearings, 21 inches.

Engine No. 2—cylinders, 36 inches and 57 inches x 30 inches; steam pipe, 10 inches diameter; exhaust, 18 inches; diameter crank shaft, 16 inches; length of bearings, 28 inches.

Another 1500 horse power engine, designed and built by the Lake Erie Engineering Works, Buffalo, N. Y., has just been installed. Dimensions of cylinders, 23 inches and 48 inches x 36 inches; speed, 120 revolutions per minute.

CONDENSERS, PUMPS AND COOLING TOWER.

The condensing plant consists of one Worthington surface condenser, one Worthington cooling tower, two combined air and boiler feed pumps and two circulating pumps of the rotary type. The rated capacity of the plant is 33,750 pounds of steam per hour, but it will take care of overloads up to 49,500 pounds per hour with but slight reduction in vacuum. It is guaranteed to produce a vacuum of not less than 22 inches at above rating and under the worst conditions of service; 25 inches under fair and average conditions, and 26 inches under the best. These conditions vary with the humidity and temperature of the air. The condenser has 34,000 square feet of brass tube cooling surface.

The cooling tower, Fig. 7, located on roof is 18 feet diameter, 29 feet high and its filling or cooling surface is composed of galvanized iron pipe cylinders. It has duplicate fans located on opposite ends of the same shaft drawing air into the tower. These fans are driven by a belted motor in pent house on top of building.

There are two combined air and boiler feed pumps; one of sufficient capacity to handle the water required by the 1500 horse power engine, and the other of sufficient capacity for the 750 horse power engine, and two independent rotary circulating pumps of the same capacities. These pumps are driven by direct-geared motors, so designed that the speed may be varied at least $33\frac{1}{3}$ per cent.

There are also two injectors for reserve boiler feeds, each having a capacity of 11,250 pounds of water per hour, and capable of handling water of any temperature below 125° F.

FOUNDATIONS.

All the foundation work in this plant (except chimney) consists of one part Atlas Portland cement, three parts clean, sharp sand and seven parts crushed limestone small enough to pass through a 2½-inch mesh. The brickwork used in foundations of

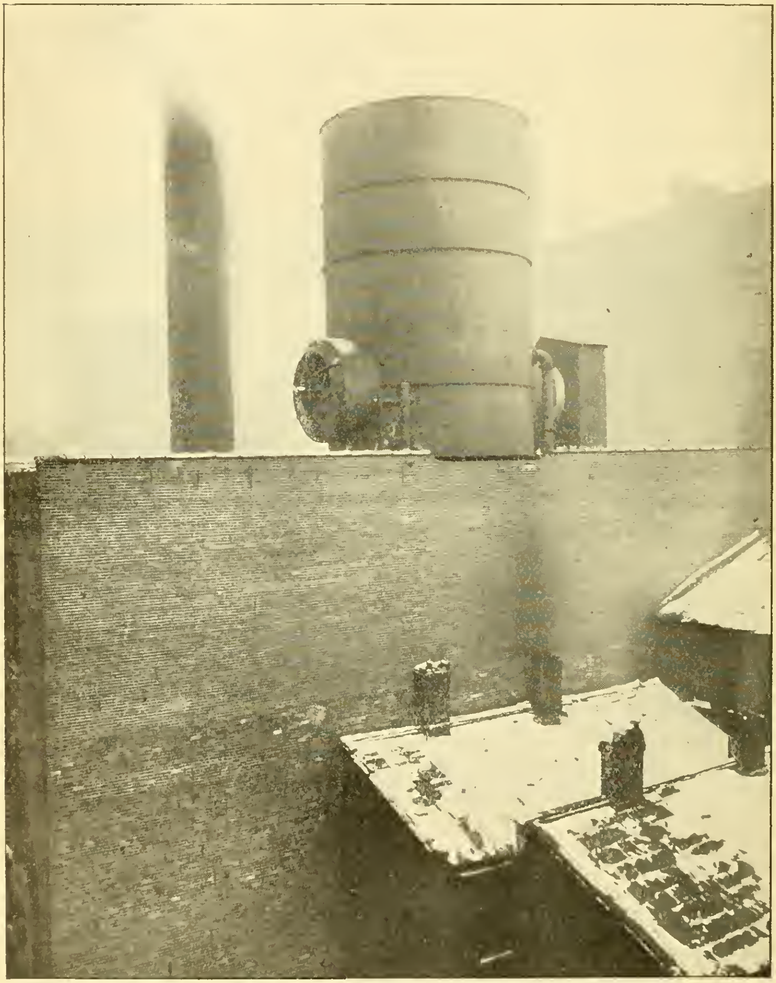


Fig. 7. Cooling Tower.

chimney is composed of hard burned brick laid in cement mortar. The engine and generator foundations extend to a depth of 13 feet 6 inches below the floor line of the engine room, and form one large monolith extending the full length of the engine and generator machinery.

POWER TRANSMISSION SYSTEM.

The engines and generators are connected by means of a patented system of power transmission (see Fig. 6), consisting of quills and internal shafts with double bearings, connected by magnetic clutches. The arrangement is intended to make it possible to drive any one, two or all three of the 500-kw. generators, and either one or both of the boosters, from the large engine in case of accident to the small engine. Two generators and one booster may also be handled by the small engine in case of accident to the large one.

The generators are connected to the engines by means of magnetic couplings, so arranged that either intermediate generator or booster may be disconnected from one engine and connected to the other while all are in motion. When it is desired to start up a generator, it is brought up to speed as a motor and then connected to the engine by the magnetic clutches.

PIPE WORK.

The entire high-pressure system is designed to operate under a working pressure of 175 pounds per square inch, and was tested to 250 pounds hydrostatic pressure. All fittings are extra heavy. All pipe above 3 inches in diameter has flanged couplings and fittings. All bent pipes are made of steel, and bent hot and of long radius. All valves on live steam pipes and on the feed water connections under boiler pressure are bronze seated. All valves above 10 inches in diameter are by-passed. The cylinder jackets, reheaters, separators, steam headers and the entire pipe system is drained by means of the Holley system, returning the water directly to the boilers. There is a combined hot well and oil filter located between the condenser and boiler feed pumps. All the pipes are covered with magnesia. A steel exhaust pipe is provided for use when condensers are not in service, and extends through the roof near the stack. Each engine has a Cochran separating receiver located near the main throttle valve. Oil extractors are located between exhaust pipe and condensers. A suitable blow-off tank is provided and connected to boiler furnaces, oil extractors and other hot water drains, with suitable discharge to catch-basin, which in turn overflows to sewer.

CRANE.

The engine room is spanned by an electric traveling crane (shown in Fig. 6) with independent motors on the lifting, traveling and transfer motions. The capacity of the crane is 15 tons at 10 feet per minute, and it has a maximum speed of 30 feet per minute

at lighter loads. The maximum speed of travel is 80 feet per minute, and the maximum transfer speed 40 feet per minute. The motors are of 20, 15 and 5 horse power respectively, and are designed by the manufacturer as a part of the crane and built substantially into the framework of the structure. This crane has proved itself one of the most useful appliances about the plant.

GENERATORS AND BOOSTERS.

There are three 500-volt constant-potential electric generators, built by the Siemens & Halske Electric Company of America, of the internal ironclad-armature type. They are designed specially to

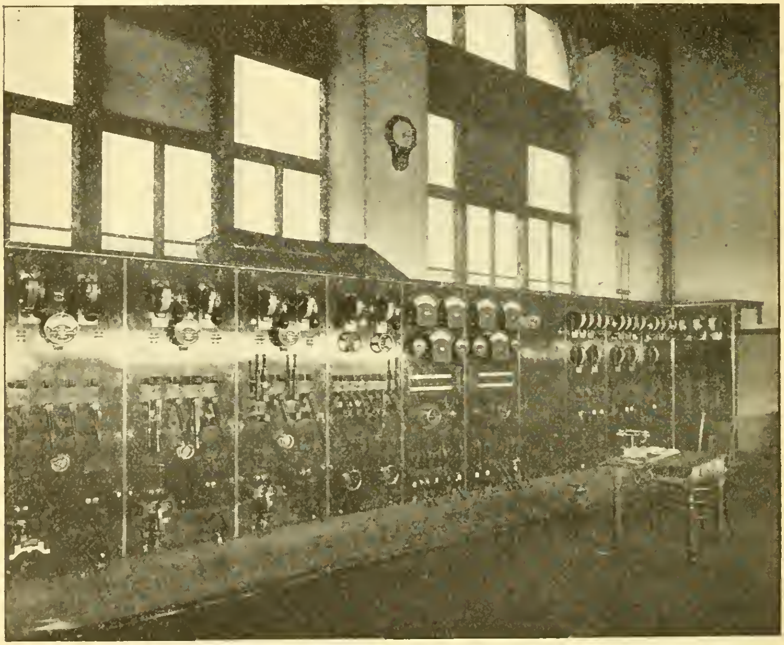


FIG. 8. SWITCHBOARD.

fit the system of power transmission adopted. The field frames of the generators may be slid parallel with the shaft a sufficient distance for reaching the armature for repairs. The capacity of each generator is 500 kw. at 525 volts when operated at 150 revolutions per minute. At this rating the rise in temperature of the armature will not exceed 40° C.; of the field, 35° C.; of the commutator 50° C. The generators are guaranteed for an overload of 25 per cent. for two hours, and $33\frac{1}{3}$ per cent. for one hour, with a 50 per cent. momentary overload without injurious sparking. They will not flash at the commutator when the circuit breaker opens at 50 per

cent. overload. The commutators are of large diameter, insulated with mica and designed for carbon brushes. The brushes are proportioned for 25 amperes per square inch of contact with rated load, and have hand wheels for both adjusting and lifting. One megohm of insulation resistance is specified between conductors and frame. The guaranteed efficiencies of these generators are as follows:

At ¼ load	88	per cent.
At ½ load	92½	"
At ¾ load	93½	"
At full load	94	"
At 25 per cent. overload	93	"

There are two separately excited shunt wound boosters, each of 50-kw. capacity at 150 revolutions per minute, and capable of carrying 500 amperes and delivering any voltage from zero to 130 volts. The boosters are of the same general construction and design as the generators, except that the field frames are divided vertically. Two more generators of the same capacity are being made at present by the same company.

SWITCHBOARD.

The plant contains a composite switchboard, Fig. 8, of 2-inch black marbleized slate, containing three generator panels, one booster panel, two battery panels, one wattmeter panel, three feeder panels and one voltmeter panel. These are carried upon an angle iron frame standing directly upon the floor. Each generator panel contains two pilot lamps, one dynamo galvanometer, one 1500-ampere amperemeter, one 600-volt voltmeter, one single pole circuit breaker, one dynamo field rheostat, three single pole double throw 1500-ampere switches and one single pole single throw switch. Each generator panel also contains one special Don Shea patent field switch, so that generators may be operated either bus-exciting or self-exciting, as desired.

The booster panels contain the two rheostat handles for the booster field regulators, two amperemeters and the necessary single and double pole switches for the proper operation of the plant.

On the battery panels of the board the following instruments are mounted: Two 1200-ampere double reading amperemeters, four 600-ampere double reading amperemeters, two 300-volt round pattern voltmeters, two 5-volt round pattern voltmeters, two 50-point voltmeter switches, four end cell switch indicators, four sets of motor contact switches for operating motors on end cell switches, which are located in the battery room, and the necessary single pole single throw switches for making the necessary connec-

tions between battery, bus-bar and boosters. There are four end cell regulating switches located in the battery room, each of 600 amperes capacity, with points for connecting fifty end cells. Each switch is provided with a motor and gearing which are operated from the battery panel of main switchboard, and the position of the contact switch is shown at all times by the end cell indicators on switchboard. These switches may be operated by hand if desired,

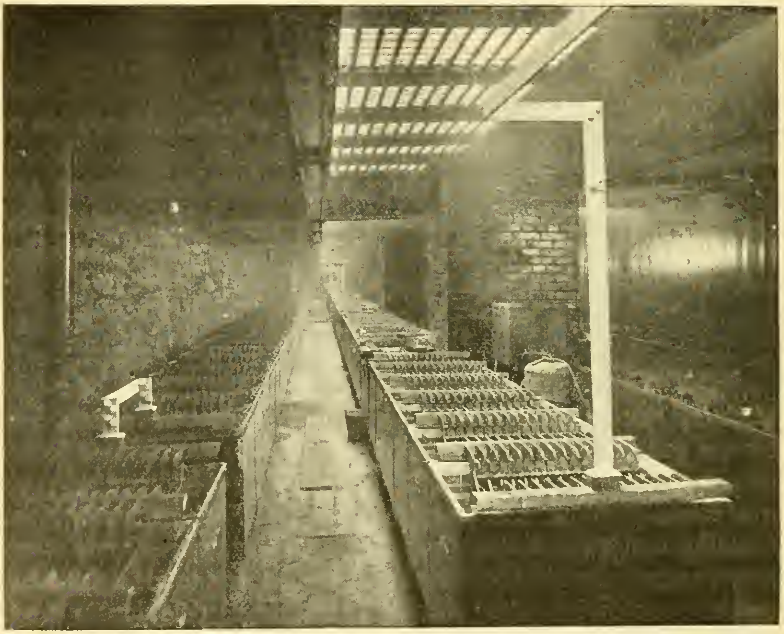


FIG. 9. STORAGE BATTERY.

with the motor completely disconnected. Each motor is capable of handling the two end cell switches on each side of the circuit, although in practice the two are operated in multiple during times of heavy discharges.

The wattmeter panel is unfinished at present, but is designed to carry when completed four 6500-ampere 250-volt wattmeters.

Upon the feeder panels five feeders are connected, each having an amperemeter and double throw single pole switch of 1500-ampere capacity on the positive and negative sides and a double reading amperemeter and single throw single pole switch of 500-ampere capacity on the neutral cable. The voltmeter panel carries one 500-volt voltmeter and two 250-volt voltmeters, each with a suitable switch for connecting to the various pressure wires. Each

panel on the board is surrounded by an ornamental copper molding, and is lighted by two incandescent lamps. All amperemeters and voltmeters except those on the battery panels are edgewise instruments.

There are four bus-bars on the switchboard; one high positive, one low positive; one high negative, and one low negative. There are also positive and negative charging busses. The generators are so arranged that each generator may be operated on either high or low bus-bars, either in multiple or separately. For convenience in handling, the right-hand switches are made positive, and the upper throw of switches connects to the high bus. Each of the two end cell switches on each end of the battery may connect either to the high bus or low bus, or to the charging bus. The two boosters in the plant may each be connected either between high bus and charging bus, low bus and charging bus, or between low bus and high bus, on either side of the system. The boosters may be connected in series either between low positive bus and neutral or between low negative and neutral. These combinations provide for charging the battery under all conditions of service, and at the same time maintaining it upon the line as an equalizer of the pressure. Also, either side of the battery may be completely disconnected, or the entire battery cut out of service and the balance of the system maintained by means of the two boosters connected together in series and operating between the neutral and either side of the system.

All the electric connections between generator and booster and switchboard are made of asbestos-covered copper cable run underneath the floors and supported upon porcelain holders. The connections between battery and switchboard are made by means of copper bars, lead-covered and painted with an acid-proof paint, and supported upon porcelain racks. The battery is connected through switches to the bus-bars and outside circuits without the intervention of either fuse or circuit breaker. Two additional generator panels of the same design have lately been added to take care of the additional dynamos contracted for.

STORAGE BATTERY.

There are 280 cells, Fig. 9, of the Electric Storage Battery Company's accumulators, each containing thirteen positive Manchester type plates and fourteen negative chloride plates. These are contained in lead-lined wooden tanks which are supported on large porcelain insulators resting upon 4 x 6-inch beams. The elements themselves in each cell rest upon heavy glass plates, and

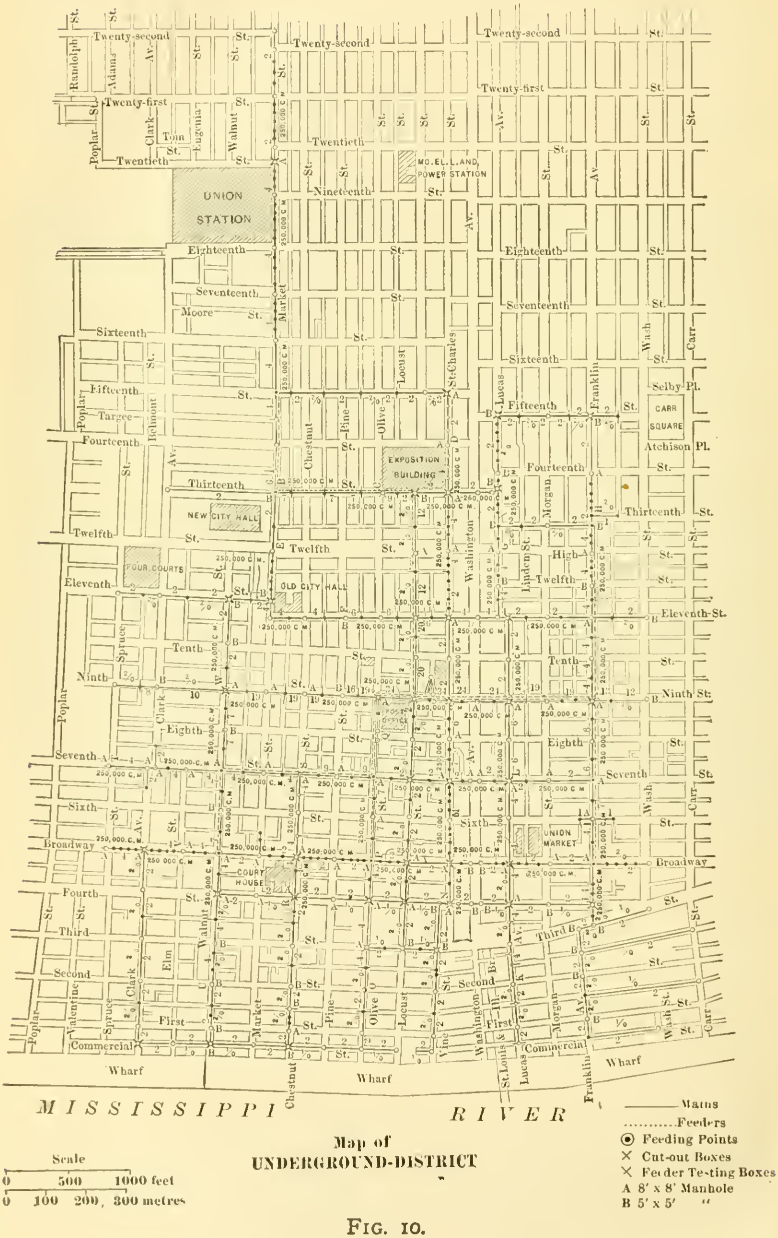

Map of
UNDERGROUND-DISTRICT
Scale
0 500 1000 feet
0 100 200, 300 metres
Mains
Feeders
Feeding Points
Cut-out Boxes
Feeder Testing Boxes
A 8' x 8' Manhole
B 5' x 5' "
MISSISSIPPI
RIVER
Wharf
UNION STATION
MO. EL. L. AND POWER STATION
EXPOSITION BUILDING
NEW CITY HALL
FOUR COURTS
OLD CITY HALL
POST OFFICE
COURT HOUSE
UNION MARKET
CARR SQUARE
250,000 C. M.

FIG. 10.

are separated from each other by glass tubes. The capacity of this battery is 2000 ampere hours at a discharge rate of 250 amperes, and it is capable of maintaining a maximum discharge rate of 1000 amperes for one hour. It is guaranteed to give a discharge of 500 kw. for one hour without a drop in pressure below 1.7 volts per cell. The normal charging rate is 250 amperes, and the maximum charging rate 350 amperes.

The battery as mentioned above is located in the basement, partly under the engine room, partly under the sidewalk, in a cool, well-ventilated room. The floor is composed of vitrified tile laid in pitch upon a concrete base.

CONDUIT SYSTEM.

Many were the criticisms hurled at the heads of the city officials when they declared that all of the high-tension electric companies should occupy jointly a single conduit system. However, the city proceeded upon this line, and issued conduit rights to all the high-tension companies to the ownership of so many ducts each in a joint underground conduit system occupying one side of the street. On the opposite side the low-tension conduits of the telegraph and telephone companies were placed.

It was feared that the joint building, ownership and maintenance of a conduit system by the high-tension companies might lead to endless litigation, but a liberal application of the "Golden Rule" to the grouping of ducts and to the location of service boxes and other engineering details of the work has produced a system of underground conduits which we believe has few, if any, equals.

The high-tension conduits system consists of 3-inch cement-lined pipe laid on $5\frac{1}{4}$-inch centers, with 1 inch of concrete between pipes and 3 inches surrounding the entire group. All ducts are laid to drain to manholes. The top layer of ducts enter service boxes, which are of two sizes, 3 x 3 feet and 3 x 4 feet. Service boxes are placed at most convenient points for reaching customers, and their depth is governed by the depth of the conduit at each location. Manholes (Fig. 11) located at every street intersection, and oftener where necessary, are of three sizes, 4 x 4 feet, with 9-inch walls; 5 x 5 feet, with 9-inch walls, and 8 x 8 feet, with 13-inch walls. In depth they are all designed to be 6 feet 6 inches in the clear under the roof. They are connected to sewers wherever sewers could be reached.

The conduit system of the Imperial Electric Light, Heat and Power Company is shown on map, Fig. 10, which gives the location of the power plant, the number of ducts owned by this com-

pany in the joint conduit on each street and the location of all manholes and service boxes. It will be observed that the main trunk line runs east on Olive street and west on Locust street. The north and south trunk line is on Ninth street. The conduits as a rule occupy every other street in each direction. They were laid out with the object in view of being able to reach one end of every alley in the city with the distributing main. It was the intention to build service boxes only opposite the entrance of alleys and to distribute entirely through the alleys either by overhead pole lines or through underground distributing laterals.

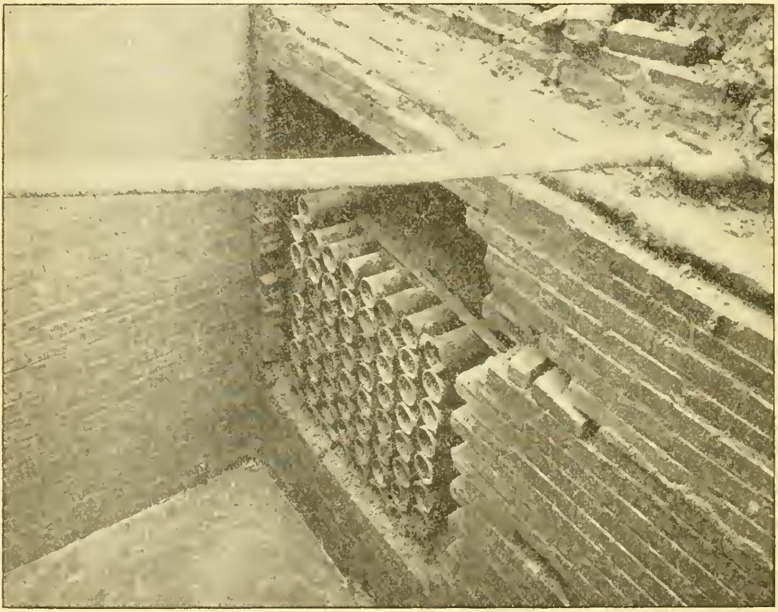


Fig. 11. Manhole of Underground System Showing Ducts During Construction.

The conduit system contemplates twenty-three feeding points, which are shown on the map marked with the letters from A to V, inclusive. The entire distribution system consists of two ducts, providing one duct for a three-conductor cable and one extra duct for city lighting or other service in the future.

Where feeders were located the number of ducts was increased to provide for them. The system as planned provides for feeders of sufficient size so that one of the largest cables would fill one duct, taking a single cable for the positive and another for the negative sides of the system. A third duct would contain the neutral feeder

and pressure wires. Another duct to contain the three-conductor main cable, and one duct reserved for future service.

UNDERGROUND CABLE SYSTEM.

While the conduit system provides space for a total of twenty-three feeders, there have been but five installed at present. They run from the power house to the points B, H, D, P and V on the first map. The map shown in Fig. 10 gives the location of these feeders, the testing boxes, pressure wires, three-conductor mains, junction boxes and lateral service cables. Each feeder consists of two 1,500,000 C.M. single conductor cables and one 500,000 C.M. single conductor cable for the neutral wire. A pressure wire of No. 16 three-conductor cable carried in the same duct with the neutral, and connected to the ends of the feeder, provides means for measuring the pressure at the feeding point by a voltmeter located at the plant. The 1,500,000 C.M. cable is made up of 127 strands of No. 10 B. & S. gauge copper, insulated with $\frac{5}{32}$-inch rubber and protected by $\frac{1}{8}$-inch covering of lead. The 500,000 C.M. cable is composed of 61 strands of No. 11 B. & S. copper, insulated with $\frac{4}{32}$-inch rubber, protected by $\frac{1}{16}$-inch lead sheath. The No. 16 three-conductor pressure cable is a solid copper conductor, with $\frac{1}{16}$-inch rubber and $\frac{1}{16}$-inch lead. The neutral conductor is only one-third the size of each of the other wires, since the entire motor business supplied by the company is connected directly to the positive and negative wires, and does not affect the load upon the neutral. It will also be observed that the feeder cables have all the same carrying capacity, notwithstanding the fact that some are nearly twice the length of others. The object of this is to economize conduit space and cost of cables by using the largest cable that can be conveniently pulled through a duct. Provision is made at the plant for keeping the pressure at the ends of all these feeders approximately equal, regardless of their length and the variation in drop, by running different voltages at the switchboard.

Each of these feeder cables connects to a single pole double throw switch on the switchboard without the introduction of any fuses or circuit breakers. Each feeder goes through two feeder testing boxes placed at convenient distances along its length, and at the end connects to the system of mains through copper fuses located in the junction boxes.

The system of mains shown on the map consists of three-conductor cables of three different sizes. No. 1-0 is used where service is lighter, and No. 2-0 where heavier, and 250,000 C.M. where

heaviest. The No. 1-0 three-conductor cables consist of 19 strands of No. 15 B. & S. copper, insulated with $\frac{3}{32}$-inch rubber. The No. 2-0 has 37 strands No. 15 B. & S. copper and the same thickness, $\frac{3}{32}$-inch, of rubber. The 250,000 C.M. cable has 37 strands No. 12 B. & S., with $\frac{7}{64}$-inch rubber. All three sizes of three-conductor main cables have $\frac{1}{8}$-inch lead cover.

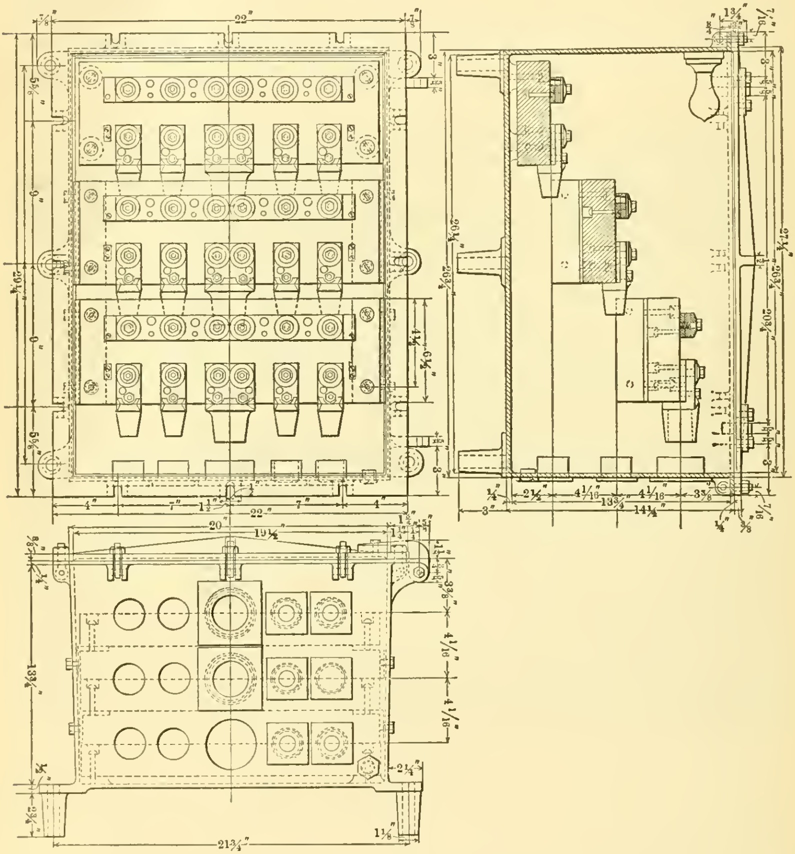


FIG. 12. FIVE-WAY JUNCTION BOX. SCALE 1-12 SIZE.

The mains are composed of three conductors, each of the same size, to provide for better distribution of pressure. The rubber tape surrounding each conductor was made of a distinguishing color for convenience in connecting, and very few errors of this kind were made in connecting together the entire system. At the points shown on the map junction boxes were placed, which are shown in detail in Fig. 12, into which these three-conductor mains

were run and connected to bus-bars through copper fuses. These fuses are each provided with a small porcelain knob for convenience and safety in handling while fusing up or disconnecting. The lead sheaths on the mains were divided and brought up through the bottom of the junction boxes and sealed water-tight by means of special stuffing boxes. The lead joint at the point of division outside the box was wiped water-tight. The cover of the junction box is screwed tight upon a rubber gasket by toggle bolts, making a thoroughly water-tight box.

The feeder testing boxes referred to above are similar in design to the junction boxes as shown in Fig. 12, although somewhat smaller and not so deep. They provide convenient means for opening the feeders for testing, the location of trouble or the making of repairs. Connection is made in these boxes by heavy copper links, which are not in any case intended to act as fuses.

The lateral service cables connecting from the underground mains to the basement of the customers' building are similar in design to the three-conductor mains, differing only in size and corresponding variation in thickness of rubber and lead. They are joined to the mains in the service boxes by means of a three-conductor soldered joint, which is carefully insulated with rubber, thoroughly taped and protected by a cast iron box. This box is then filled with an osokerite compound, thoroughly insulating and preserving the joint from all contact with moisture or other deteriorating substance. The insulation resistances of these cables were guaranteed as follows:

No. 16 B. & S. three-conductor, 1000 megohms per mile.
No. 0, 2-0 and 250,000 C.M. three-conductor, 750 megohms per mile.
500,000 C.M. single conductor, 500 megohms per mile.
1,500,000 C.M. single conductor, 400 megohms per mile.

For a break-down test the entire system was submitted to 3000 volts alternating current, and found to withstand this test satisfactorily. The insulation guarantees were also found satisfactory under accurate tests.

The insulation resistances were all measured by means of the capillary electrometer designed by H. C. Burgess, of the University of Wisconsin, and described by him at the Omaha meeting of the A. I. E. E. The results were found to be highly satisfactory. It is an extremely sensitive instrument, but is unaffected by magnetic influences or by the jarring of building. The only precaution found necessary was the great care essential to avoid surface leakage. Resistances were measured as high as 2000 meghoms.

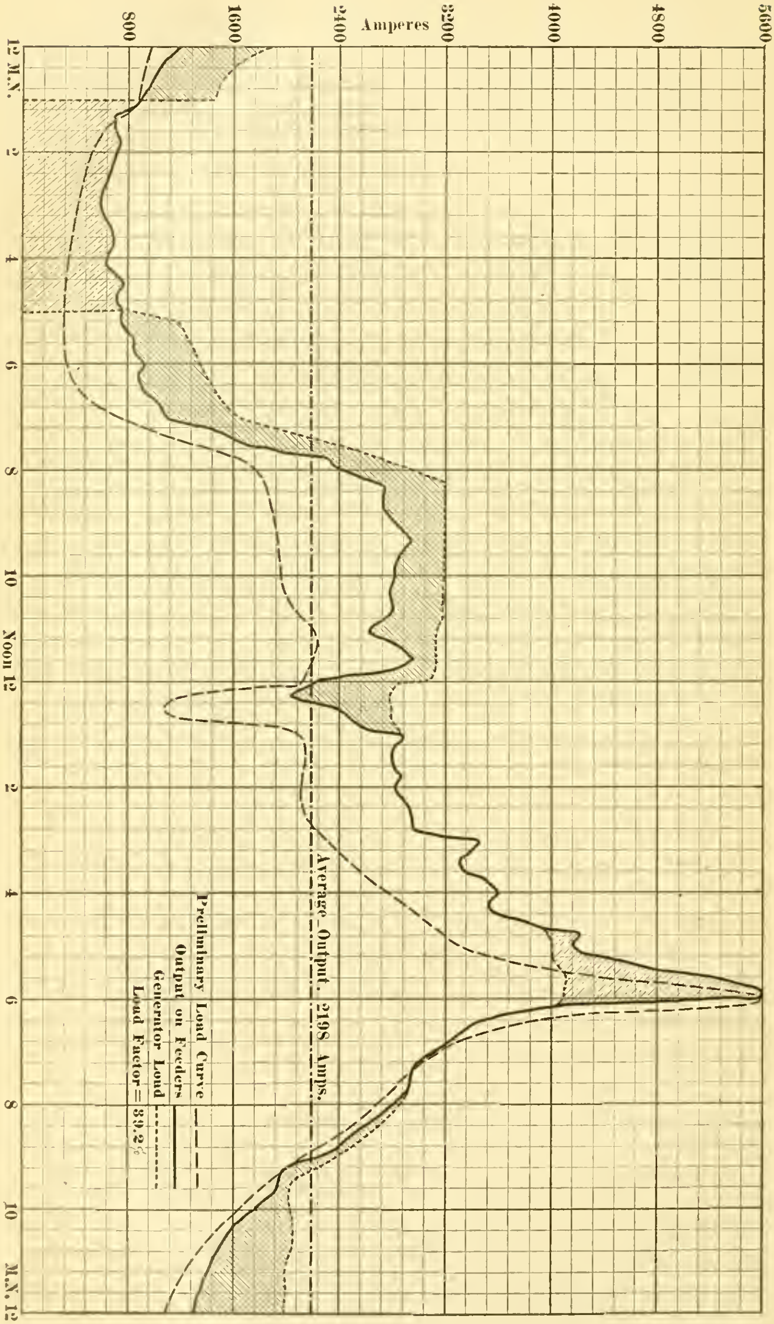


Fig. 13. Load Curves, Showing Original Hypothetical Curve and Present Actual Curve with the Use of Boxes.

The voltage used throughout most of the tests was 100 volts, obtained from a chloride of silver battery. Attempts were made to use a dynamo current from the local power circuits, thus making the test at 500 volts the maximum pressure intended to be carried in use. The attempt was a failure, due to the unsteadiness of the local power circuit and the consequent disturbance due to condenser effect in the cables. This instrument can be put to a variety of uses, although we believe this is the first instance where it has been used commercially for testing an entire system of underground cables. We have checked its results very closely with a galvanometer, using the deflection method, but the annoyance and delay incidental to the use of the galvanometer in this work prevented more than a very occasional checking.

INSIDE WIRING.

The entire inside wiring is done on the two-wire multiple arc plan. The lateral cables entering the basements of the customers' buildings are three-conductor cables, furnishing a constant potential supply of electricity at either 235 or 470 volts. All electric power service is connected to 470 volts, and the inside wiring is run open and supported on porcelain knobs, with rubber-covered wire. The incandescent and arc lamp wiring is taken off one or the other side of the system at 235 volts and run with rubber-covered wire either on porcelain knobs or cleats or concealed in an approved conduit system. All of the old-style 110-volt cut-outs were replaced. Specially designed tablet boards with terminals properly spaced for the higher voltages, and with inclosed fuses, were used throughout this work. All of the old sockets were replaced with the latest design of porcelain sockets, and where defective cord was observed it was replaced by an approved rubber-covered flexible cord. All of the inside wiring having been gone over in this way, and cleared of grounds and brought up to the latest standard of practice, has resulted in decreasing, rather than increasing, the fire risk following the introduction of the higher voltage system.

INCANDESCENT LAMPS.

The incandescent lamps used on this system are of the 235-volt type, mostly of 16 C.P., although some 10 C.P. and some 32 C.P. are in use. Also small candle power decorative series lamps. The lamps are all Westinghouse cap and porcelain base. The filaments are either double, two in series, or coiled in several convolutions. This characteristic is due to the extra length necessary on

a lamp of this voltage. The lamps were bought under guarantees regarding efficiency, life and the maintenance of candle power, which were entirely satisfactory to the purchaser. In practical operation the light has been entirely satisfactory to customers, and they compliment the character of incandescent service furnished. There were at first minor mechanical and electrical defects, however, such as the sagging of the filament until it touches the glass where lamps are not placed in a vertical position, and the short-circuiting of leading-in wires when a filament burns out near its support, all of which have been remedied in later lamps. There have, however, been no accidents or fires resulting from these causes.

ARC LAMPS.

In the original design of this plant, begun fully three years ago, it was anticipated that its principal business would be power service, and that arc lighting would not exceed 15 per cent. of the total service. The introduction, however, of the inclosed arc lamp and its remarkable popularity, due to the steadiness of the light and the facility with which its service is metered, has so increased the demand for arc lighting that the arc service is at present a very important part of the company's business. It was believed at the time that the plant was designed that arc lighting might be made secondary to both the incandescent and motor work. The 235-volt inclosed arc lamp was therefore adopted on account of its convenience, one light being controlled independent of all others. It has been found by experience that two arc lamps burning in series on 235 volts give better service than the single lamp. In cases where a single lamp must be used a satisfactory light has been obtained by increasing the current to 3½ amperes.

MOTOR SERVICE.

The entire power service is taken from the outside wires of the system at 470 volts. These wires inside of the building in all cases are treated as high-tension circuits. It might be surmised that complaint would be made regarding the power service on account of this reduction of voltage on 500-volt motors. This has not proved to be the case. The motors having been previously used upon systems varying in voltage from 450 to 550, the users of power were educated to expect a considerable variation in the speed of their motors. With a steady pressure of 470 volts at the motor terminals, none of the company's customers have complained regarding their power service.

LOAD CURVE.

It may be interesting to submit a preliminary load curve of this plant, prepared by the engineers and submitted to the company two years and a half ago, and to compare it with an average load curve of the plant at present. We have reduced the scale of the former and plotted them side by side on the same sheet. These curves are shown in Fig. 13. Their correspondence in shape is interesting. Their points of difference are explained by the increase in the arc business above referred to. This curve also shows one of the great advantages of the storage battery. The entire plant is shut down from one o'clock until five in the morning, and the load carried upon the battery. The machinery is then started and the battery charged during the forenoon, allowed to float upon the system during the afternoon and discharged during the peak in the evening, as shown upon the shaded portion of the curve; and again charged considerably during the first half of the night before shutting down. Interesting features are the large all-night load and the comparatively low peak or maximum load. The average output for twenty-four hours is 2198 amperes, which is 39.27 per cent. of the maximum load.

SPECIAL FEATURES.

The distinguishing features of this plant which marked it as advanced engineering practice are:

First. The 220-440-volt system of distribution.

Second. The entire system is underground.

Third. The battery equalizer and auxiliary.

Fourth. All subsidiary apparatus is electrically driven.

Fifth. Fuel economizers with induced mechanical draft.

Sixth. Condensing apparatus with cooling tower.

(a) The wisdom of selecting the double voltage system will be appreciated when it is stated that the saving in copper alone in the district covered by this plant is equal to half the cost of the building and entire station equipment. This system was almost unknown at the time of its adoption here, but several plants using it have since then begun operation in Europe, and another large installation is being erected in this country. The system is reliable, safe and satisfactory in its service to the public.

(b) The undergrounding of all wires is the ideal method of distribution as regards public safety, reliability of service and low depreciation and repairs.

(c) The value of a storage battery as an equalizer of pressure and as an auxiliary to the steam plant is universally admitted. It

has proved indispensable on many occasions in this plant. Its readiness to take all burdens thrown upon it, whether accident to plant, short circuit in underground cables or sudden demand for light caused by a thunder storm, needs only to be experienced to be appreciated.

(d) Driving all boiler feed, circulating and air pumps, elevator, fans, etc., by electric motors saves the condensation in all subsidiary steam pipes, as well as avoids the wasteful use of steam incident to this class of apparatus. By using steam only in the large cylinders of the compound condensing engines and driving all minor apparatus by motors, it is estimated that a saving of about 10 per cent. on the entire output of the plant is realized.

(e) Fuel economizers give all the water entering the boilers an additional temperature of 100° F., which effects a saving of about 9 per cent. in the use of fuel. With coal at $1.50 per ton, they will earn annually about 25 per cent. on their cost.

(f) With all losses deducted, it appears that condensing apparatus as here employed make a saving of from 15 to 20 per cent. in fuel, thus earning a large return on its cost.

The entire station equipment was included in one contract, under rigid guarantees from the contractor covering the efficiency of the plant as a whole. A definite cost of coal per kilowatt hour delivered to outside circuits from the switchboard was guaranteed under a forfeiture in case of failure, with an equal bonus for increased efficiency above the figure specified. It was intended to give in this paper the results of these tests, but, as they are not completed, no report can as yet be made.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. NOVEMBER, 1899. NO. 5.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ALTERNATING-CURRENT POWER MOTORS.

BY W. A. LAYMAN, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, April 5, 1899.*]

COMMERCIAL applications of the electric current are broadly divided between, first, those involving direct current; second, those involving alternating current. Both forms of current are so well understood, and the development of apparatus for the utilization of them is so well advanced, that, within certain limitations, either may be used for a great variety of purposes. Examples of this are to be found in arc lighting, incandescent lighting, power motor work, street railway service, electric heating apparatus, etc. It cannot be said that either form of current can be used with equal *facility* and *economy* in these several directions, but development has advanced to such a point that prominent electrical men are not able to agree on the exact dividing line where the advantage of one form of current ends and that of the other begins. Remarkable strides have been made in alternating-current applications, and results are now accomplished with this current that a few years ago were declared not only improbable, but impossible. Notably is this the case in the power motor field. A decade ago the alternating-current motor was little more than a laboratory plaything; to-day its practical and efficient adaptability to power work of all kinds is generally conceded.

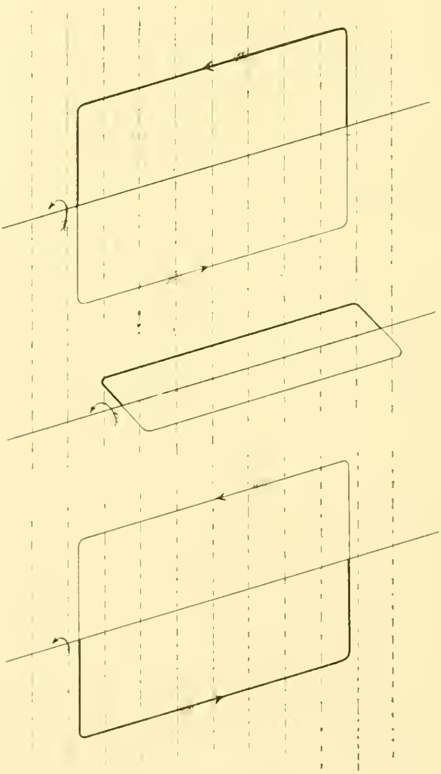
It may be incidentally recalled that there was much controversy as to whether the great Niagara plant should generate direct or alternating currents, all arising from the claim that there was no certainty of ever having a commercially practicable alternating-

*Manuscript received October 4, 1899.—Secretary, Ass'n of Eng. Socs.

current power motor. To-day this power plant is generating forty to sixty thousand horse power, all in alternating current, and a large part finds application in power motor fields.

(A) DIFFERENCE BETWEEN DIRECT AND ALTERNATING CURRENTS.

If there exists in a given space what is termed a magnetic field, and if an electrical conductor is quickly moved across this space in a direction angular to the direction of the magnetic lines of force, as they are technically called, an electric pressure is generated in



FIGS. 1, 2 AND 3.

this conductor; and if the conductor is a closed loop, under proper conditions as to algebraic relation of the pressures created, an electric current will flow around the loop.

In Fig. 1 such a magnetic field, with a loop of wire revolving in it, is shown. Here the plane of the loop is parallel to the direction of the lines of force, and in its rotation, in the direction indicated by the arrow below the figure, the loop is cutting across the lines of force and generating a current flow, as shown by the two

arrow-heads on the sides of the figure itself. In this position the loop is cutting these lines of force at the maximum rate of speed, and therefore generating its maximum pressure. As the plane of the loop revolves toward a position at right angles to the lines of force the rate of cutting decreases, and when the horizontal position is reached, as in Fig. 2, this rate of cutting is zero. As the rotation further continues (Fig. 3), the sides of the loop begin to cut the lines of force in the reverse direction, thus generating pressures and

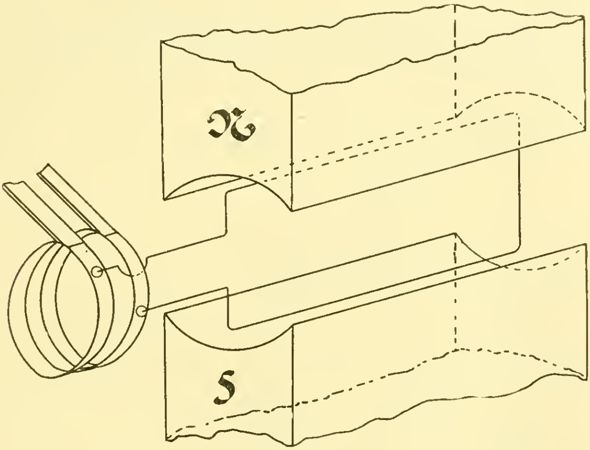


Fig. 4.

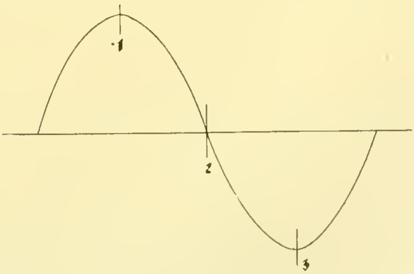


Fig. 5.

currents of opposite sign to those in Fig. 1, as indicated by the arrow-heads.

It is apparent that a loop so revolving generates a pressure and also a current wave which changes sign as the cutting, relative to the direction of the lines of force, is changed, rising slowly from zero to a maximum positive, and then back through zero to a maximum negative. Such a wave, diagrammatically plotted with reference to time, is shown in Fig. 5.

Figs. 4 and 6 illustrate an extension of this principle to the dynamo electric machine. N and S represent the magnetic poles, in the space between which there exists a strong magnetic field. The loop of wire in Fig. 1 now becomes the revolving armature. Instead of being closed upon itself, however, it is open at one end, and the open ends are connected to revolving rings. Upon these rings brushes bear which carry the current out into the exterior circuit and back again. Through such an exterior circuit, with the construction shown in Fig. 4, a true alternating current would flow, as is shown in Fig. 5. If in such a dynamo the loop revolves at the rate of eight thousand complete turns per minute, the cur-

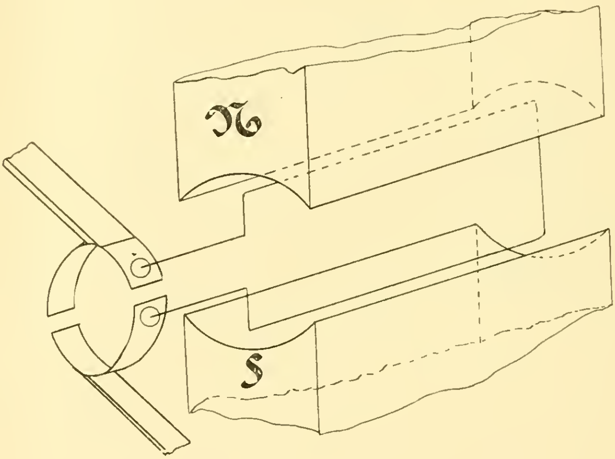


Fig. 6.

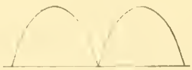


Fig. 7.

rent will be one of sixteen thousand alternations, or half waves, per minute, which is one of the standard frequencies of commercial alternating current of to-day.

To produce direct current, or current in which the flow is always in one direction, and of practically constant magnitude, it is necessary only to substitute for the two revolving rings of Fig. 4 one split ring, as shown in Fig. 6. By so placing the brushes (bearing upon the two half rings) as to cause them to stand on the breaks in the ring when the armature loop is in the zero generating position, a reversal of the negative portion of the alternating wave of Fig. 5, in so far as the external circuit goes, is accomplished.

By this reversal a single loop of wire would generate a form of current such as is illustrated in Fig. 7. This would be uni-directional, but pulsatory in character. To reduce this from such a form to a true direct or constant-pressure uni-directional current requires but a multiplication of generating loops, the commutator being still further subdivided to provide two connections for each loop. The external circuit is therefore in contact with the ends of any one loop through a small portion of a revolution only, and the effect is to send out into the circuit only the high-pressure sections of a great many waves, as shown in Fig. 8.

If it were desired to generate two independent alternating-current waves, this might be done by introducing independent armature loops, displaced from each other by a definite angle. If this angle were 90°, two such loops would generate pressures in quadra-

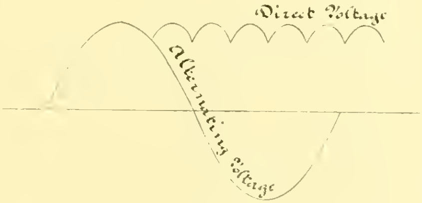


FIG. 8

FIG. 9.

ture, or differing in phase by 90°. Such waves, plotted, would near the relation shown in Fig. 9. Similarly, three independent loops set at 60° to each other would be made to generate, by proper connections, currents differing in phase by 120°, as shown in Fig. 10. In this manner are produced the two-phase and three-phase currents of practical application to-day, these currents being illustrated in Figs. 9 and 10 respectively.

(B) DIRECT- AND ALTERNATING-CURRENT MOTORS.

Similarly, I may briefly discuss the fundamental differences between direct- and alternating-current motors.

A very early development in the application of electric current was the discovery that both forms of dynamo, as shown in Figs. 4 and 6, were reversible in process. That is, with a given magnetic field and a source of current from the outside, each form of arma-

ture would, with its corresponding form of current supply, run as a motor *under proper conditions.* With Fig. 6 the limiting condition was that the brushes should be so set upon the commutator as to send the direct current into any given armature loop at that instant when this loop occupied such an angular position with reference to the direction of the lines of force of the magnetic field as to provide a turning couple between the lines of force and the loop, this action arising from the fundamental consideration that magnetic lines of force attract or repel conductors carrying electric currents, according to the direction of the flow of the current in the conductor.

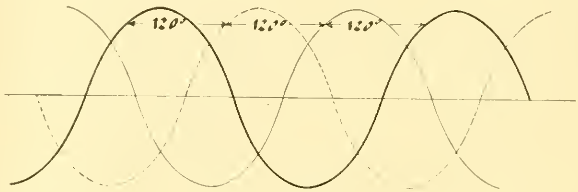


FIG. 10.

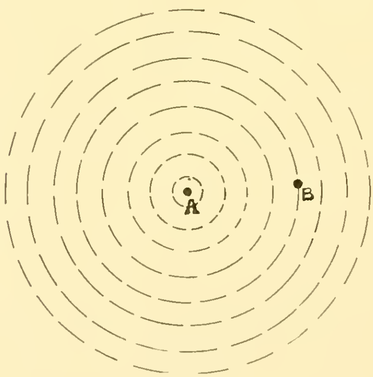


FIG. 11.

In Fig. 4 the limiting condition was to have the loop revolving at such a rate as to cause it to move into the position of reverse cutting of lines of force simultaneously with the change of direction of flow of the current supply. In other words, the loop had to revolve in step with the alternations of the current supply, otherwise the attractive and repellent forces would neutralize or interfere with each other. Such a motor, therefore, had to be brought up to synchronous speed, as it is termed, before it would run with load. For several reasons, other than this great disadvantage of

not being able to start, the synchronous motor was not deemed commercially practicable for power work in general, and even to-day has only limited uses.

The next step was to endeavor to make an alternating-current motor along the lines of Fig. 6. In other words, it was attempted to use the direct-current motor on alternating currents. Since the direction of rotation of the armature of a direct-current motor is the same, so long as the relation between the armature windings and the field windings remains unchanged, it was assumed that the motor could be easily used on alternating currents.

If sudden changes of direction of the current were to occur at long intervals of time apart no serious consequence would result, and the motor might prove satisfactory; but with periodic changes of direction of great rapidity, such as would exist with an alternat-

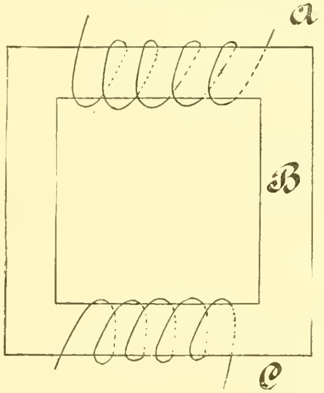


FIG. 12.

ing current, a new element is introduced. *With an alternating magnetic field currents may be generated in stationary coils of wire.* An electric current flowing through any wire sets up a magnetic field around the wire. If this current is alternating, an alternating field follows, the lines of force expanding and contracting in concentric circles with each alternation of the current. Such a field is shown in Fig. 11, A being the conductor through which flows the current producing the field. If a second conductor, as B, is brought into this field the expanding and contracting lines of force cut across B, and by this cutting induce alternating currents in B.

An application of this principle is found in the static transformer. When a coil of wire A, as in Fig. 12, is wound upon an iron core B, and at another point on this iron core a second coil C is wound, an alternating current flowing in A sets up alternating lines of force, which are, by reason of its magnetic conductivity

being better than that of air, drawn into B. These lines of force generate an alternating current in C, hence the dynamo (for the transformer is a dynamo) has in this instance its armature C stationary while the magnetism revolves.

It is largely this transformer action which makes the direct-current motor a failure when operated on alternating currents. The effect of this action may be seen in Fig. 13. The coil C, which is a portion of the armature winding, is in the position where, by its rotation alone, it is generating no electrical pressure, and therefore supplying no current to the outside line. In a direct-current motor, where the magnetic field is constant, this wire is practically dead at this instant, and the brush bearing upon the two commutator bars which are connected to the ends of these loops of wire, notwithstanding that it short-circuits this coil for an instant, causes no sparking.

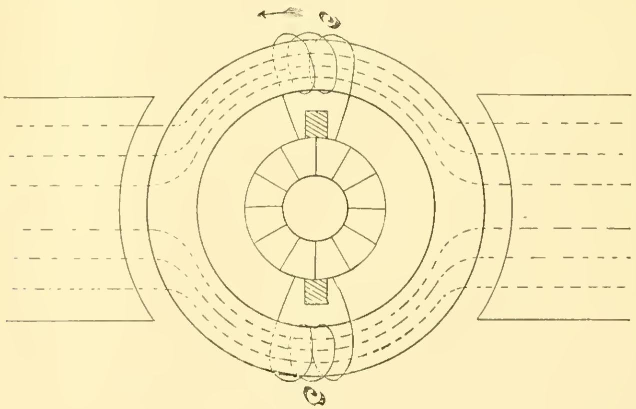


Fig. 13.

With an alternating magnetism, however, the coil is in position to act as the secondary of a transformer, and the short circuit through the brush causes a current flow which produces a spark when the brush passes onto the succeeding segments of the commutator. This sparking is such as to make continuous operation in this manner impracticable.

Alternating-current motors, therefore, remained a practical failure until an entirely new principle of operation was discovered. This was the principle of the so-called induction motor. The induction motor is a species of alternating-current transformer. It corresponds to the transformer in having the three elements of (1) a *primary winding*, into which current is fed from the supply circuits; (2) *an iron circuit*, or *series of circuits*, in which alternating

magnetism is set up by the current flowing in the primary winding, and (3) a *secondary winding,* in which currents are induced as it cuts the magnetic lines of force produced by the primary winding. This primary winding corresponds to the *field winding* of the direct-

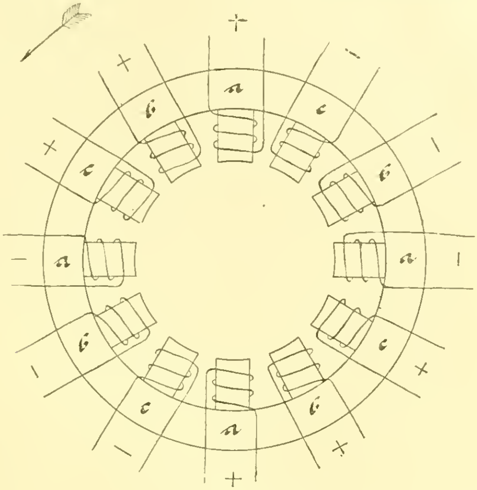


FIG. 14.

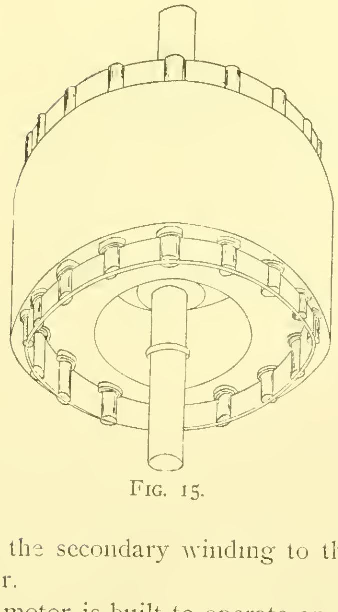


FIG. 15.

current motor and the secondary winding to the *armature* of the direct-current motor.

The induction motor is built to operate on either the ordinary alternating current shown in Fig. 5 or on currents of two or more

phases. This form of motor attained its first practical development in this country at the hands of Tesla, who found, after much experimenting, that commercial results could be secured in such a motor if currents of two or more phases were used to produce a so-called rotating magnetic field. He found that he could produce this rotating magnetic field by having on his motor two or more entirely independent field windings. By giving these windings the same relative position in the motor as the different phases of his

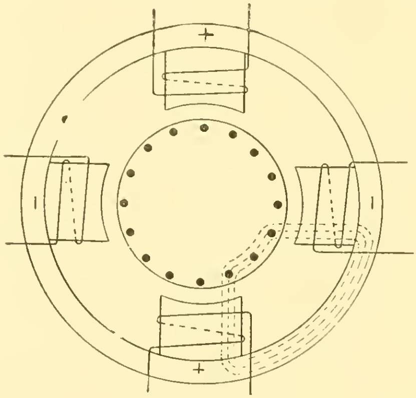


Fig. 16.

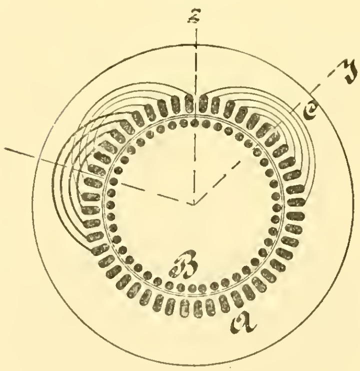


Fig. 17.

supply current bore to each other, he found that he could produce the effect of a strong magnetic pole revolving around the surface of his armature at a speed, in revolutions per minute, depending upon the frequency of alternations of his current. In a motor such as that shown in Fig. 14, for example, he wound what would ordinarily be a 12-pole machine in such a manner as to give him three sets of 4 poles each (thus producing a 4-pole machine), into

which he could introduce three phases of current supply. One phase, supplying a set of poles AAAA, produced poles the strength of which followed a periodic wave just as did the alternating supply. At any one instant such a pole might be positive. As its strength began to decrease a second phase of current, supplying a set of poles BBBB, caused a gradually increasing strength of pole which had the effect of shifting the pole from A to B, and so on. For such a field winding it was, in course of time, found advantageous to use a form of armature illustrated in Fig. 15. In this armature the winding of copper conductors consists simply of a large number of bars completely short-circuited at both ends, with respect to each other, by a copper ring. The resemblance of this

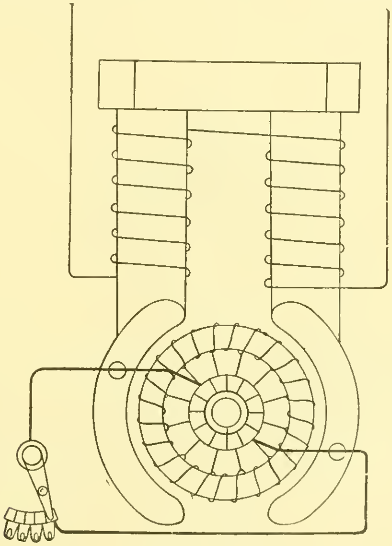


FIG. 18.

form of winding to an old-style squirrel-cage gave rise to the popular name of a squirrel-cage winding. Such an armature placed in a rotating magnetic field will start from rest with a large torque, and will quickly run up to a speed slightly less than the number of alternations of the current supply divided by the number of poles of the winding. In other words, if the motor in Fig. 14 were supplied with alternating currents of 7200 alternations per minute the speed of rotation of the armature would be slightly less than 1800 revolutions per minute, there being four poles of the winding.

Such a motor supplied with single-phase currents, as for example Fig. 16, however, will not start from rest. This is due to the following reasons:

The currents generated by induction in the armature conductors when the armature is standing still select such paths of flow as to produce no turning couple. Some of the currents tend to produce rotation in one direction, while others tend to produce rotation in another. They thus nullify each other in so far as turning moment goes. In the two-phase and three-phase motors, however, a different condition exists. The currents produced in the armature by any one set of poles bear the right relation to the poles of the next phase to afford an effective turning couple, and therefore the multiphase motors are very effective in starting from rest. Accordingly it is not surprising that very soon after the discovery of the induction motor and a reduction to practice of the principles of generating and transmitting two-phase and three-

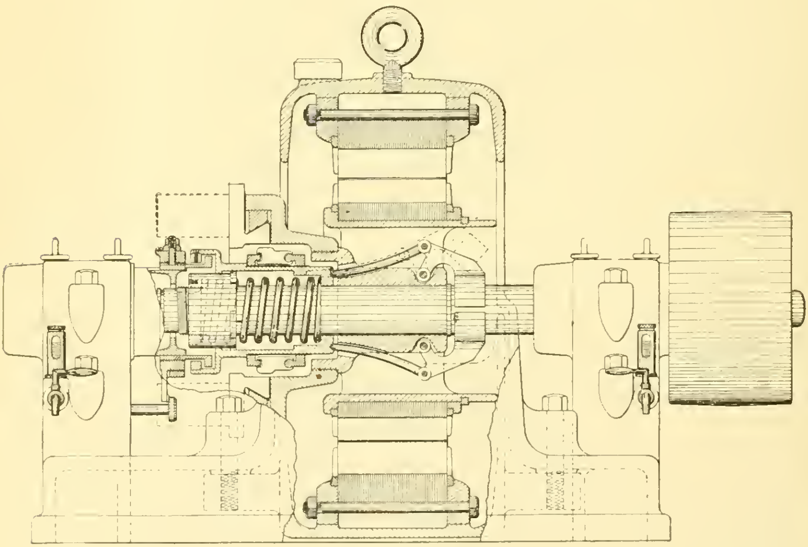


Fig. 19.

phase currents excellent two-phase and three-phase power motors were placed upon the market. Those manufacturing companies owning the two-phase and three-phase patents were not slow to develop a complete system of two- and three-phase power transmission, utilizing induction motors satisfactory to a very high degree.

Great inducement existed, however, to produce a satisfactory single-phase motor operating along the same general lines. First of all, a very large percentage of the alternating-current central

stations in existence made it necessary, if these plants were to supply alternating-current power motor service, either to develop single-phase alternating-current power motors or to discard their old generating apparatus. Further than this, if good single-phase motors could be produced which would not introduce disturbing

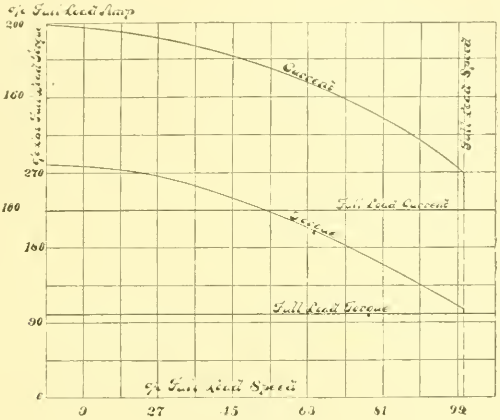


FIG. 20.

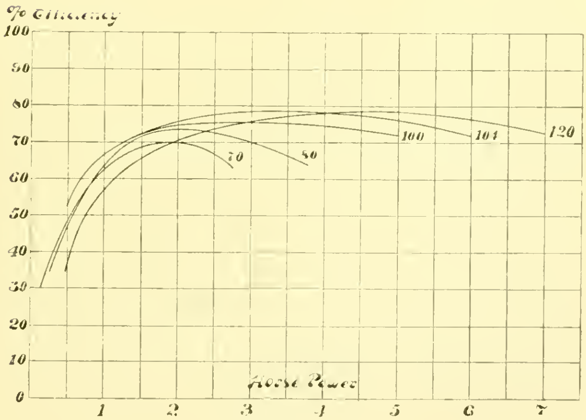


FIG. 21.

effects, in so far as lighting service was concerned, a single-phase system would possess very material advantages over the two-phase or three-phase system.

Therefore the aim of many investigators has been, even since the advent of the successful two- and three-phase motors, to develop and offer to power users generally a thoroughly practical

and commercial single-phase power motor. Such a motor has been brought out by the Wagner Electric Manufacturing Company, of St. Louis, and it is of this motor that I desire to speak in detail. The mechanical construction of the motor is in many respects like that of the two- and three-phase motors on the market. A field is built up of iron plates very much like A of Fig. 17, and an

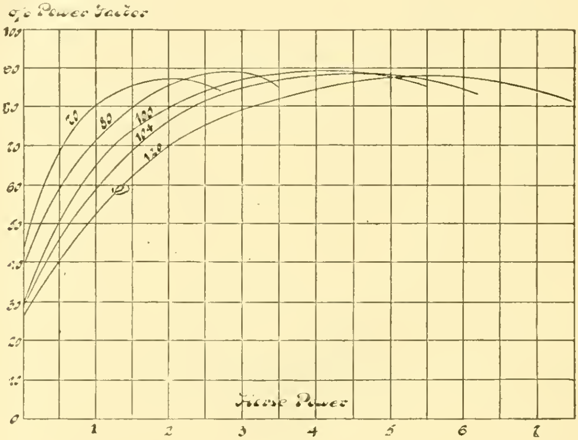


FIG. 22.

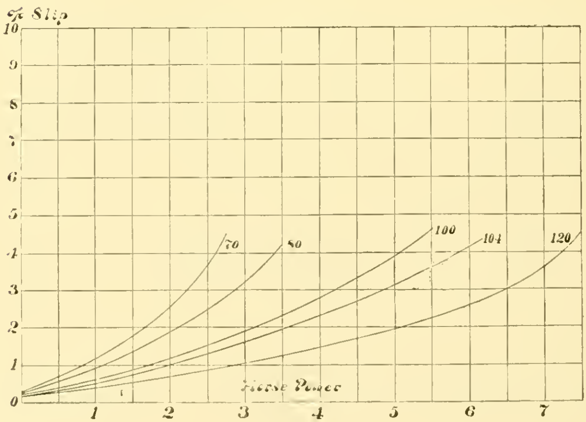


FIG. 23.

armature core is also built up from iron plates very much like B of Fig. 17. The field is wound with coils threading through the slots of the punchings, as shown at C, Fig. 17, so as to produce a magnetic pole of intensity varying from a maximum along the radius XY to zero along the radius XZ. For motors of 60 cycles and in smaller sizes it is customary to make these field windings 4-pole.

The armature cores are wound with an ordinary direct-current progressive winding, connected up to a commutator in exactly the same fashion as in the direct-current motor winding. The commutator of this armature is so designed that it may be completely short-circuited by introducing a short-circuiting circle of copper segments. When so short-circuited this winding affords a substitute for the squirrel-cage form of winding, differing from the squirrel-cage in

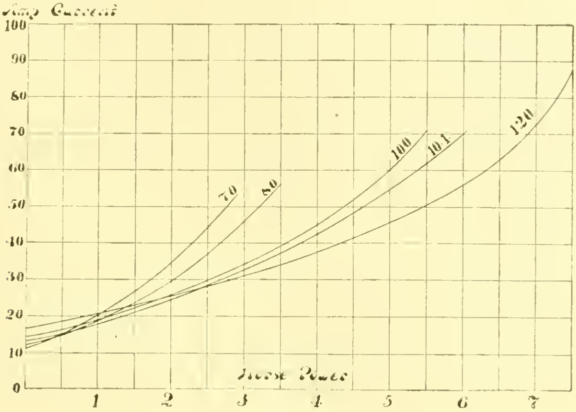


FIG. 24.

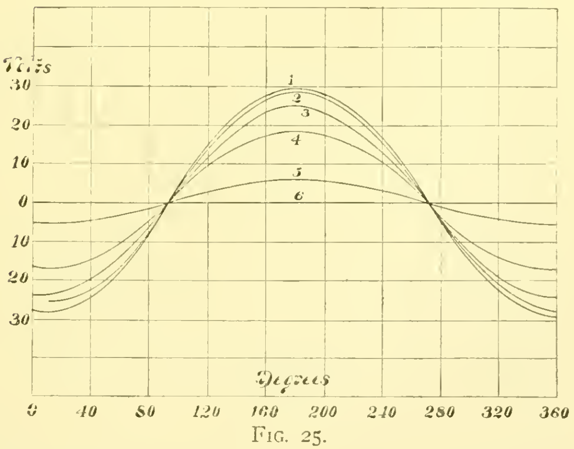


FIG. 25.

that, instead of the currents being left to select paths for themselves, they are restricted to flowing in paths afforded by the individual coils of the armature winding. The operation of this motor is based wholly upon the principle that an induction motor with a completely short-circuited armature will, when up to the running speed, operate on single-phase current supply in exactly the same manner as it operates in a two- or three-phase motor with two-

and three-phase current supply. In other words, the disadvantage of the single-phase motor, as compared with the two- and three-phase motors, disappears when up to running speed. Therefore, in developing a successful single-phase motor, the problem to be met was the provision of a starting device which would afford ample starting torque at all speeds between rest and running speed

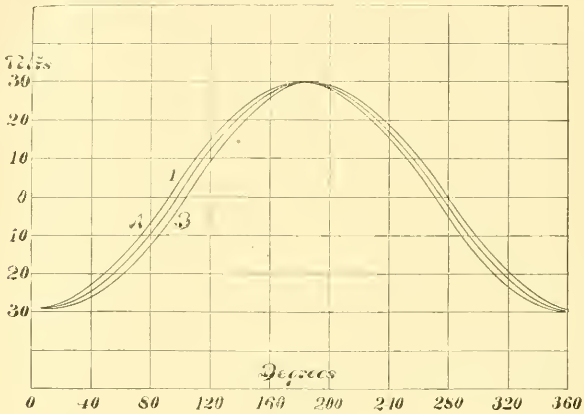


Fig. 26.

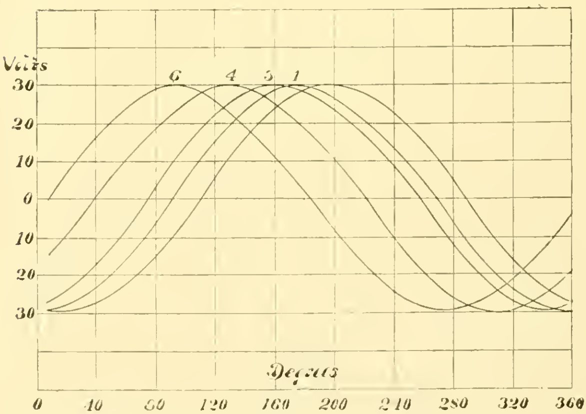


Fig. 27.

without excessive consumption of current, and of a mechanical construction equally durable with the rest of the motor. In doing this the Wagner Company has developed to a high degree of mechanical and electrical perfection a type of motor equal in all respects, and superior in several, to the best forms of the direct-current motor. In effect, this motor starts with the same characteristics of torque and current consumption as does the ordinary series-wound direct-

current motor, such as is found in all street car equipments, for example. The armature winding is short-circuited through carbon brushes bearing upon the commutator surface. The field generates, by induction, currents in the armature winding, which currents flow out through the carbon brushes either into an outside resistance or, where a direct short circuit of the brushes is provided, out through one brush and back into the armature through the other. By the shifting of the brushes on the commutator surface these armature currents are forced to take such positions, relative to the magnetic poles produced by the field, that a repellent action between these armature currents and the poles of the fields is effected and rotation results. In other words, the currents which would be ineffective in an armature construction such as was shown in Fig. 15 are forced to take such positions that they become equally effective with

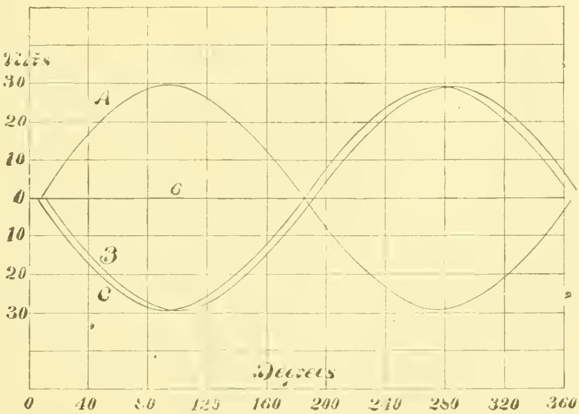


FIG. 28.

the currents produced in the armatures of two- and three-phase motors. This arrangement of affairs, illustrated in Fig. 18, is employed in bringing the motor up to running speed. When running speed is attained the brushes are no longer required, and the armature winding is completely short-circuited, after which the armature runs purely as does the armature of a two- and three-phase motor.

In the mechanical development of this form of motor many novel features have been introduced. The commutator is of the radial, instead of the horizontal, type. The short-circuiting band is made up of small copper links, which links, being in turn mounted upon a short-circuiting ring, are thrown into the annular opening in the commutator, and by making close contact with each segment produce a very effective short-circuiting of the entire armature

winding. In the operation of the motor it is very advantageous to have this short-circuiting accomplished either at the running speed or very slightly below. To remove all uncertainty on this score, the Wagner Company's motors are built with an automatic device for performing this operation. This device consists of a set of governor weights acting against a spiral spring. The centrifugal action of the weights will, at the proper speed, force the short-circuiting links into the commutator against the action of the spring. At the same instant, and by the same means, the brushes bearing upon the commutator are thrown off, and therefore, in the running condition, the motor runs with much less noise than does the direct-current motor. (See Fig. 9.) These motors are so designed as to carry a large percentage of overload without serious consequence. If this capacity for overload is exceeded this type of motor will

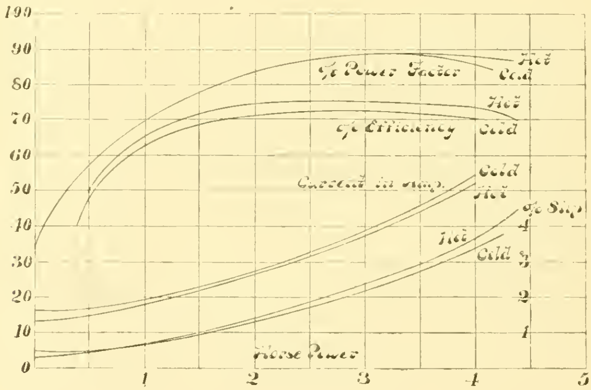


Fig. 29.

come to rest in exactly the same way as will a two- or three-phase motor under the same conditions. If the overload is temporary the motor will, without any further attention, run back up to speed, as in slowing down the brushes are thrown back on the surface of the commutator by the automatic device, and the motor is again placed in the starting condition.

In its electrical design this motor has been as highly developed as in its mechanical features, and the builders claim for it results practically identical with the best that have been secured with the two- and three-phase motors. The important characteristics of such a motor are its starting torque, consumption of current in starting, consumption of current while running idle without load, power factor, efficiency and slip. The starting current of this motor can be varied at will to meet all requirements of the service. This is accomplished by shifting the brushes upon the commutator

surface. If large starting torque is essential, the proper placing of the brushes will produce this, the current consumption bearing practically a direct ratio to the amount of torque. If a very small torque only is essential, the starting current can be reduced to a very small amount. The motors, when they leave the factory, are so adjusted as to provide sufficient torque to bring up their full load. The relation of starting torque to starting current is shown in Fig. 20. The energy required to operate the motor without load is very small, being practically the same as that required by direct-current motors. The efficiencies which have been secured in these motors are practically identical with those secured in the best direct-current motors. The power factors are as high as those secured

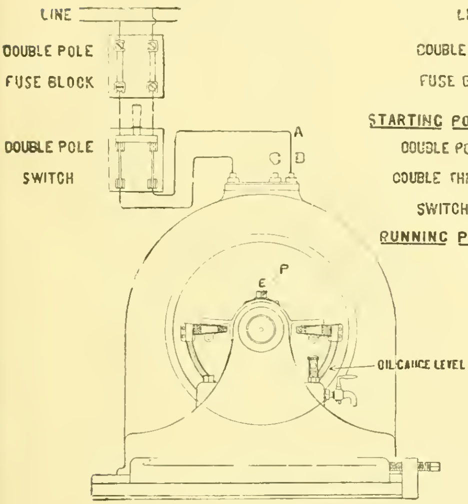


Fig. 30.

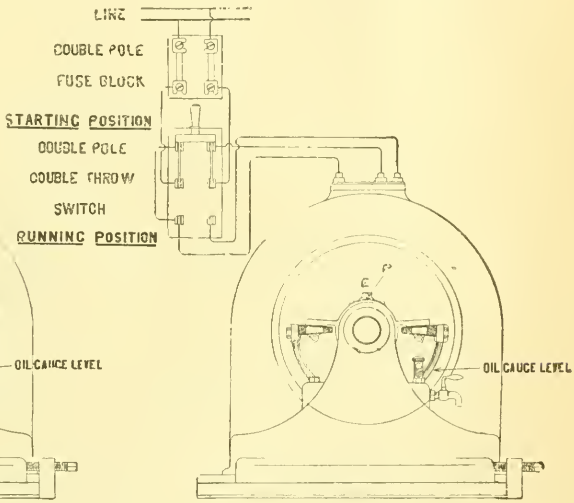


Fig. 31.

in two- and three-phase motors, and the slip is very small indeed. By this latter factor of slip is meant the decrease in speed between no load and full load. It may be said that this is about the same as in a good shunt-wound direct-current motor. In Figs. 21 to 28 I have shown the results of a test made by students of the University of Nebraska, during the spring of 1898, upon a 5-horse power motor. These tests were made under the direct supervision of Professor R. B. Owens. One set of tests was the measurement of the various electrical factors with different applied electrical pressures at the terminals of the motor. In other words, the motor, as sent out by the builders, was designed to operate on a pressure of 104 volts and on 60 cycles. Tests were made with a variation of this voltage in steps between 70 and 120. The effect of these

various voltages upon the several factors are very nicely illustrated in Figs. 21 to 24, inclusive. The judiciousness of the ratings given by the builders is, I think, very clearly brought out in these curves. A particularly noticeable feature is the small percentage of slip at the rated capacity of the motor,—namely, 3 per cent.

Another set of tests was made by these gentlemen for the determination of the exact magnetic actions going on in the motor. In other words, they attempted to determine, under all conditions of load, as well as when standing idle, the exact form of magnetic field produced by their single-phase sign-wave current supply. To determine these measurements they introduced exploring coils in the slots of the field punchings. Each of these exploring coils embraced

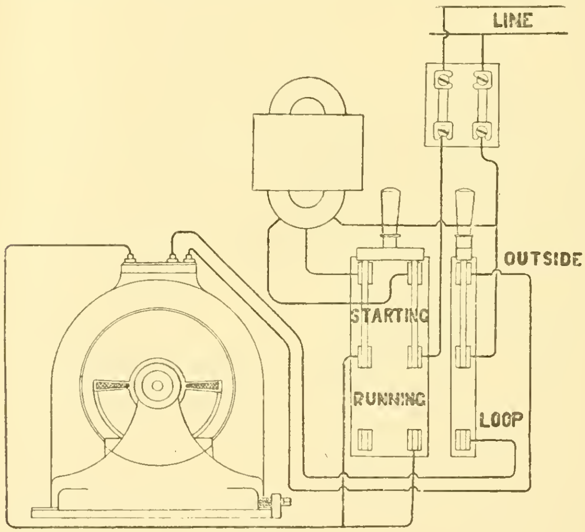


FIG. 32.

one-fourth of the slots of the entire field punching, corresponding in that way to the exact breadth of the polar winding of the motor. These exploring coils were introduced progressively around the frame in such a way that the first one enclosed the entire winding of one pole, the next one eight-ninths of the winding of one pole and one-ninth of the winding of the next pole; the third one enclosed seven-ninths of the winding of one pole, and two-ninths the winding of the next, etc., progressively, until a point was reached where half of one pole and half of the next pole were enclosed. By the proper introduction of measuring apparatus the experimentors could accurately determine at any one instant the magnetic strength in the section of the field embraced by each coil.

Therefore, plotting these instantaneous results with respect to time, they could determine the exact form of a wave and its net numerical value all around the interior surface of the field punchings. In Fig. 25 the results of their tests are shown with the motor standing still. The result here is just what might have been expected,—namely, that in this condition of affairs the field is a pulsating one, and decreases in magnitude at any instant as we progress around the circumference of the field from the central radius of each pole. In Fig. 26 is shown the reactive effect of the armature upon the strength of the field immediately in the center of each pole-winding between the limits of no load, half load and full load in one direction. The displacement seems to correspond in percentage to the percentage of slip. In Fig. 27 are plotted the reactive results on the magnetic field, caused by the rotation and the current of the armature winding. A close study of these curves, as compared with the curves of Fig. 25, reveals the fact that the armature reactions of the motor when up to speed are such as to change entirely the character of the magnetic field, actually producing as perfect a rotating magnetic field as is created by a multiphase current supply. In Fig. 28 is shown the reactive effect of the armature upon that portion of the field embraced in the exploring coil, which gives a horizontal line in Fig. 25. Here Curve 1 shows that the resultant magnetism enclosed by this exploring coil is zero when the motor is at rest. Curve 2 shows the condition of affairs with the motor running in one direction. Curve 4 gives the corresponding result with the motor running in the other direction. Curve 3 shows the displacement of 4, due to load of the motor. These various magnetic curves are worthy of much closer study than can be given them within the limits of this paper.

Another test made by the university students was to determine the effect of continuous load upon the motor; in other words, to compare the electrical conditions of the motor operating cold and hot. These results are shown in Fig. 29, and disclose the fact that the motor is more efficient and operates with better results in every respect, except slight increase in the percentage of slip, when hot than when cold. In the winding of these motors it is possible for the builders to secure a variety of results. In other words, where a very large starting torque is required an auxiliary connection can be made, the effect of which is to rate up the motor in capacity. The builders term this a loop connection, and for this connection they provide a third terminal upon the terminal board. If the circuit is connected to this terminal and the common terminal for starting, 50 per cent., 75 per cent. and in extreme cases 100 per

cent. overload may be brought up to running speed. When up to running speed connections are changed by means of a throw over switch in the supply circuit, so that the current is supplied to the normal winding of the field. The diagram for connections in such circumstances is shown in Fig. 30. Where the starting torque required is normal, the diagram for connections is as shown in Fig. 31. If it is desired to limit the starting current for the purpose of avoiding line drop of pressure, the builders furnish a small transformer for reducing the pressure applied to the motor terminals. The connections under such circumstances are as shown in Fig. 32, and the result accomplished is the cutting off of that part of the torque and current curves of Fig. 20 above the 150 per cent. line. The extreme simplicity of the motor arises from the fact that it can be connected upon the same circuit with incandescent lamps, and that it operates without any disadvantageous effects on incandescent circuits. Furthermore, operating on a low tension, there is no danger from accidental contact. If it is desired, however, to operate on higher voltages, windings will be provided to correspond. The manufacturers have designed alternating-current motors of this character up to and including 20 horse power capacity for 60 cycles, and 15 horse power for 133 cycles. It is understood that larger sizes are to be brought out in the near future. It may be said in passing, however, that practically the limit of requirement for ordinary commercial power purposes is 50 horse power capacity. The limit of adaptability of this motor to various descriptions of power work is set by the necessary frequency of starting, as above explained. The motor cannot be continuously operated upon the commutator, and so long as the starting is of infrequent character satisfactory results can be guaranteed. For ordinary running service, where starting but a few times a day is necessary, the life of the commutator is indefinite, and motors are running in the shops of the Wagner Company, which have been in service for two years or more, the commutators of which have never received more than a very limited amount of attention.

PATENTS AND MONOPOLY.

By John Richards, Member Technical Society of the Pacific Coast.

[Read before the Society, November 3, 1899.*]

Before entering upon the main part of the subject to be presented, and in order to define the limits of the paper, I will explain that there is no intention to sustain or to condemn the policy of granting patents for inventions. The equities and conditions that surround this phase of the subject, such as that occult faculty recognized in law, the inventive faculty, and the inherent rights arising therefrom, would lead into long and profitless discussion.

Twenty-eight years ago I wrote a pamphlet, much more extensive than the present paper, to contend that inventions in the useful arts should not become the property of individuals when such inventions or discoveries were deducible from common premises, the results of science and acquired skill, and that priority in inventions consisted generally in the discovery of wants.

Such speculations, interesting as they may be to follow out, are of no practical value in the face of the fact that nearly all civilized countries, Holland excepted, have patent laws or systems of granting an exclusive use of new inventions. It is not, therefore, a theory we have to consider, but a condition.

While the system of granting patents for inventions has remained measurably the same for a quarter of a century past, the industrial interests affected thereby have been greatly changed and centralized, establishing, or tending to establish, a new relation of personal rights in invention. This is the principal theme of the present paper, and is in every way, I think, a suitable subject to be brought before this Society, which alone on this coast is in position to discuss a problem of so technical a nature as the relations between inventions and industry, and in how far the best relation can be established by the patent laws and the methods of procedure in the bureau.

In the American *Review of Reviews* for June, 1899, in the editorial notes, under the head of "The Rights of Monopoly," there appeared the following remark:

> The Government Patent Office every day grants control over certain inventions with the avowed object of promoting for a term of years a strict monopoly. If, in some field of industry not dependent upon the protec-

*Manuscript received November 15, 1899.—Secretary, Ass'n of Eng. Socs.

tion of the patent laws, a monopoly should arise by reason of the fact that a single individual or firm or corporation had come into control of the entire production of a given article, it would not follow necessarily that there was any greater propriety in this particular monopoly than in those especially fostered by the Government under its patent laws.

It is a curious conception that places patents for inventions in the category of monopolies. There is scarcely even analogy between a patent and what is commonly understood by monopoly. The inventor must, before he enters upon an exclusive use of his own discovery, prepare it for public use at the end of a term of years, averaging fifteen, by means of carefully executed specifications and drawings, which, if faulty, incomplete or insufficient to disclose fully his invention, invalidate his right of exclusive use. This does not appear like monopoly.

In its nature a patent is simply a compact between an inventor and the public, whereby he is for a limited time permitted on certain conditions to use exclusively what is already his own by natural right, on condition of disclosure and dedication to public use at the end of a term scarcely long enough to develop his invention; he paying all the fees for registry and conveyance to the public and something more than this, because at this time in this country inventors have overpaid such expenses to the extent of nearly four millions of dollars, now lying in the National Treasury.

In the case of authors and their writings the terms are more liberal. The period of personal right is longer, is renewable and is more carefully protected by law. The fees of registry are merely nominal, and encouragement is in every way extended, as it no doubt should be, on grounds of expediency as well as of equity and right.

The history of patents for inventions fully discloses their nature. The various patent systems of the world may all be said to rest upon a modification of an old English law called the Statute of Monopolies, which, previous to 1633, had led to various abuses by special grants or privileges, called "patents," that were sold or bestowed by the crown upon favorites. Such grants, then considered "acts of grace," were given for an exclusive right to make or sell special commodities, even the common necessaries of life, such as salt, which was once the subject of a patent. This was monopoly.

The abuses under this law, the Statute of Monopolies, became so intolerable that it was repealed in 1633, except in so far as inventions were concerned, and was in effect superseded by the present statute, which confines personal monopoly to "inventions," or what was "new in the realm," so that no citizen should be abridged in any right he had previously enjoyed. Section 6, on which the patent laws rest, reads as follows:

Provided that any declaration before mentioned* shall not extend to any letters patent and grants of privilege for the term of fourteen years or under hereafter to be made of the sole working or making of any manner of new manufactures within this realm to the true and first inventor of such manufactures, which others at the time of making such letters patent and grants shall not use, so as also they be not contrary to the law nor mischievous to the State, by raising prices of commodities at home, or hurt of trade, or generally inconvenient, the said fourteen years to be accounted from the date of the first letters patent or grants of such privilege hereafter to be made, but that the same shall be of such force as they should be if this act had never been made, and of none other.

As before remarked, this old law has stood for 266 years as the foundation on which patent laws are founded in all countries where such rights are conveyed to inventors. It was obvious to Parliament that no monopoly could exist in respect to inventions, and these were accordingly excluded in the repeal of the old law.

Sir Edward Coke, the great English jurist, defining the scope of the revised statute, said:

An illegal monopoly is a grant or allowance from the king by his grant, commission or otherwise to any person or persons, bodies politic or corporate, of or for the sole bringing in, selling, making, working or using anything whereby any person or persons, bodies politic or corporate are sought to be restrained of any freedom or liberty that they had before, or hindered in their lawful trade.

Numerous authorities could be given showing that not only are patent grants for invention free from the feature commonly understood as monopoly, and are no restraint upon the rights of the commonwealth or of persons, but also that, notwithstanding these clear facts of history, the old original concept of a monopoly patent has lingered for more than two centuries, as is seen in the quotation given at the beginning of this article and in others to be hereafter noted. As a matter of fact, patents for inventions, since 1633, instead of constituting a monopoly, have been a limitation of a natural right that inheres in the person, the equity of such limitation resting on an assumed probability that within a certain period of time the public would by other means become possessed of the same discovery.

Nothing is confirmed by a patent grant. It is simply a warrant of privilege to appeal to the courts for the protection of a personally created new property, and even this right, as before pointed out, is made conditional on the fact of an originality which the inventor must himself, at his own expense, establish, in most cases against prejudice and nice discriminations of a technical nature scarcely definable in set laws.

---

*Referring to the act repealing the Law of Monopolies.

The patent laws of the United States were instituted 160 years later than those of England, and, while differing in many provisions from the British system, recognize fully the principle, laid down in the repeal of the Statute of Monopolies, that no grant should bar from use or enjoyment any knowledge or right held by any one before the discovery or invention patented.

One distinction from the British system is in the meaning attached to the name "inventor."

In the quotation from Chief Justice Coke it will be noticed that he includes, with discovery, "sole bringing in." This yet constitutes "invention" in Great Britain and some other countries. In fact, the term, etymologically considered, means to "bring in," being derived from the Latin *in* and *venire,* to come in, or bring in, and applies especially to the introducer of an invention or to "communications from abroad"; but there are provided reasonable safeguards to prevent abuse of this privilege.

In the United States the limitations are more strictly drawn. Inventions are made purely personal, without power of delegation from a living inventor. He alone can procure a patent, and should error be made by false or mistaken statement, so as to abridge the rights of an earlier inventor, the statute provides means of correcting such mistake and confirming the grant to the actual first inventor, thus carefully protecting not only the public but each individual against the infraction of any privilege previously enjoyed.

The Constitution of the United States confers upon Congress the power to grant, for a limited time, to authors and inventors, an exclusive right to their writings and discoveries for the promotion of science and the useful arts. This took form at the end of the last century by the enactment of a patent law which in 1870 was revised and put upon a more permanent basis, which has lasted without material change to the present time, and which, with an exception to be hereafter mentioned, has operated in a satisfactory manner.

This law, under the circumstances of our time, furnishes almost the sole means whereby a small industry can be started and carried on, notwithstanding that for fifty years or more patented inventions were a common basis for extensive industrial organizations.

In manufactures so founded individual skill was the prominent and often the main factor. Men without capital were able to acquire and control interests in various industrial enterprises, especially such as grew out of small individual beginnings founded on patents for inventions. Now circumstances have changed. In

the enormous activities of modern industrial development individuality is practically eliminated, and various means of monopoly have arisen.

Such means consist in the control of legal and other employed skill; the purchase of material and supplies at a reduced rate; reduction in the cost of transportation; borrowing money at low rates of interest; reducing the expenses of management; saving in the expenses of advertising; raising the price of the product, with many other advantageous conditions which go to make up monopoly and occupy the former place of patented inventions.

In this manner there has arisen a conflict of interests and a jealousy of patented inventions that will no doubt in the near future lead to attempts at modifying the patent laws, or to a new construction of them by the courts that will impair the rights of inventors. Even at this time we have a decision in which by an unparalleled dictum a Federal judge has set aside an important and generally recognized patent* by deciding a *want of invention.* Such an assumption was contradicted by facts, testimony and the opinions of those skilled in the art. If one patent can be destroyed in this manner, why may not any other meet the same fate The judge of a court may from facts decide questions of infringement and of novelty, because these rest upon fact, and skilled aid can be called in to clear up history and technical features; but when a court assumes to determine the *degree of invention* in a case, this leads into a field that has no limit and to the exercise of functions that belong to the skilled officers of the Patent Office. An officer of the law, not skilled in the arts, is not competent to set up a measure of invention.

The whole world seems engaged in a wild race for gain. The commercial incentive becomes stronger each year, and the frantic attempts to adapt laws to the new circumstances show the slow and unwieldy nature of legislation and the difficulty of framing "rules of action" for new arts and interests. In one decade, or even in half that time, may arise discoveries and economic changes that greatly affect the social relations of people; and this rapid and revolutionary march of centralization and the altered social conditions produced thereby are the primal causes of unrest and the many turbulent social problems that are at this time forcing themselves on the attention of thinking people.

The effect of an attack upon the patent system, and the results that would follow in the social, economic and industrial interests of

*U. S. Circuit Court, District of Northern California, Johnson *vs.* Woodbury, No. 11,934, 1899.

the country, are matters of serious import. Even now a small manufacture of any commodity of common use is impossible unless the product or process is protected by a patent. Hence the incentive to disparage and impair such protection by classing it with "monopoly."

There are now enrolled in Congress no less than seventy bills that would, if enacted, affect the patent laws or procedure. Some of these bills are for useful purposes, and more of them are not. Some of them have their initiative in personal objects, and many indicate a want of information respecting the nature and equities involved in patent grants.

There is no sufficient understanding of patent matters in Congress any more than there is among the people; besides, there is the impediment to the consideration of such bills that they are of a national character, and lack the usual incentives to promote their consideration. So the subject is neglected, while the Patent Office, with an enormous surplus fund lying in the National Treasury, is without even the required room and facilities for transacting its business.

Fortunately, however, an association of leading members of the bar and patent attorneys at Washington, many of whom have held executive positions in the bureau, give consideration to new bills affecting patent laws and procedure. The *Patent Law Association* considers the various proposed changes, publishes digests of new bills and may be said to control legislation to the extent of preventing the enactment of new laws and rules that would lead to bad results. It also promotes what tends to improvement of the system.

To illustrate the methods of this organization, the *Patent Law Association* in November, 1898, published a bulletin containing a digest and review of pending Congressional bills, and, in respect to two affecting the trade-mark law (H. R. No. 2807 and H. R. No. 3128), has this to say:

> Of the many lawyers to whom these bills were presented for criticism not one indorsed any of them. The singular lack of precision, joined with the comprehensive scheme of the undertaking and the insistence with which they were urged, makes these bills peculiar examples of what must be met by all associations and individuals who have at heart the real advantage of the law and the good of all.

Two characteristics of the American Patent Bureau are noteworthy,—the purity of its administration and its paternalism.

Throughout the century of its existence there has never arisen any serious case where the integrity and good faith of the officers

have been called in question. They are in a great measure free from the baneful influences of political preference, and have maintained a spirit of independent action strange to find among so much of an opposite character. The popular confidence thus gained has rendered possible the present "paternal" features of procedure.

By paternalism is meant the elaborate system of examination performed by subordinate officers clothed with the power of witness, counsel and judge. A "triple function" it may be called. Each primary examiner exercises all of the functions of the bureau up to appeal; adducing testimony as to the novelty of inventions, the relation and bearing of such testimony and then *passes judicially upon his own findings*. This work, if advisory, or if it resulted in "objection," would be as logical as it is useful, but it is not consistent with the fact that there is no corresponding power to "confirm." It is a proceeding that acts in one way only.

An applicant has to assume the whole responsibility when his application is "allowed." Infraction of his patent gives him the privilege of complaint in the courts, but nothing more. If his case is rejected he has no standing or privilege, no matter what the real facts may be.

During procedure he is put in the position of a humble petitioner praying for the allowance of his claims, asking for all he can get and taking what in the examiner's opinion he should have. This constitutes a paternal system, and is responsible for the widely prevalent opinion that an "allowance" of a patent is at the same time a confirmation of its validity.

This paternal system gives rise to the existence of incompetent attorneys and to faulty methods of procedure, because both inventors and their agents depend on the office and commonly present their cases in an imperfect or overdrawn form, based on the rule, "Claim everything, and get what you can." Out of this form of procedure arises the common opinion that a patent is an "act of grace,"—a favor and privilege emanating in and conveyed by the Government.

This conception of patents for inventions furnishes logical grounds for the charge of monopoly. It also presents a vulnerable point of attack by those whose interest it is to destroy property in invention. This mode of procedure is not necessary, as is proved by the fact that repeated and invalid patents are as common in this country as those where the applicant and his attorney assume the responsibility of novelty and the governments deal only with form.

Competent attorneys who prepare here applications for patents in foreign countries will understand this peculiar method of pro-

cedure in domestic cases, and are governed accordingly. For the American office they will draw a large number of ambiguous claims, approaching the novel features of the invention from various sides, introduce technical language not capable of being understood in a popular way and in amendments proceed to hair-splitting distinctions.

Specifications for other countries are drawn with the essential features of the invention expressed usually in a single claim and in plain terms, describing the thing or part invented as nearly as the applicant and his attorney can determine this point, and usually in a way to secure a sound patent when there are grounds to admit of such.

It is not contended that the methods of procedure in this country can at once be altered. We have drifted into a system that permits almost any one to become a patent attorney, depending on the bureau to do the work. To change this and to make the applicant responsible in procedure, as he is in fact, would eliminate the paternal feature and at the same time remove a false conception of the nature of a patent.

Referring further to the relation between patents and monopoly, in September of the present year there assembled at Chicago a congress of men, eminent in economic matters, to deliberate on "trusts" or the monopoly exercised by these combinations. One of the delegates to this conference, Professor Jenks, read a paper before that body in which, with other suggested inquiries or problems, was one as to "whether the patent laws should not be so changed as to prevent the right of monopoly accruing to the patentee," thus placing inventions in the same category with commercial monopolies.

Mr. Bourke Cockran, of New York, in an address before the same body, said: "Now, there are three ways in which the Government interferes in the trade of the individual in this country; one is by patent laws."

He names patents first as a cheap kind of monopoly, and then goes on to recommend the suppression of monopoly by the remedy of "publicity."

How would it do, let one ask in amazement at this statement, to issue charters in the same manner as patents on inventions? For example, (1) the term to last seventeen years; (2) the applicant to file at the beginning a complete exposition of his business for public use at the end of this term; (3) to make the privilege contingent on there being no interference with rights previously enjoyed by others; (4) to declare in a publicly printed document the nature,

conditions and limitations of the grant and sell the same for five cents a copy.

This, it seems, should satisfy Mr. Cockran's desire. What he has in mind is, no doubt, to throw around all kinds of chartered privileges some such restrictions as are now applied to patents for inventions. If that were done the monopoly would be eliminated, as it is by the spirit, letter and intent of patent laws as they have existed since 1633.

Since the foregoing matter was prepared the Assistant Commissioner of Patents in this country, Mr. A. P. Greeley, has published a volume entitled "Foreign Patent and Trade-Mark Laws." In this volume are various explanations and comments on the differences in systems and procedure. On pages 18 and 19 the following will be found:

The idea that the grant of a patent for a new invention is in some way in derogation of the rights of others, and that it is for the interest of the public that the invention should be made free to any one to use at as early a date as possible, is not yet wholly overcome, even in the United States. * * * In the United States, while a patent once granted is not liable to forfeiture for any cause, the disposition to consider that the public interest demands that every technicality of the law should be taken advantage of against the patentee, particularly in the construction placed on the claims of his patent, has, it is to be feared, too often resulted in depriving a meritorious inventor of the protection to which he was justly entitled.

On pages 32 and 33 the following will be found:

The countries which can be said to have patent offices properly equipped to make anything like an exhaustive examination on the question of novelty are, besides the United States, Austria, Canada, Denmark, Germany, Japan, Norway, Russia, Sweden and Switzerland. In all of these except Switzerland a patent is refused if the invention is found to be not patentably new. Under the Swiss law, the applicant is informed of the result of the examination and given an opportunity to amend, if necessary; but if he does not do so, or insists that a patent issue, even though the invention is shown to be old, the patent cannot be refused. A similar plan is under consideration in Great Britain, and is likely to be adopted.

On page 37 the following, including a footnote, appears:

And while patents granted after preliminary examinations are very often submitted to experts for opinion as to their validity, especially if suit for infringement is to be brought on them, they are recognized, generally, as *prima facie* valid.

While this is true of all other countries in which the preliminary examination system prevails, and was true of the United States up to 1879, it cannot, unfortunately, be said to be strictly true at present of the United States.

ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND
OHIO
W.VA.
MD.
VA.
KY.
TENN
N.C.
S.C
GA.
ALA.
MISS.
ARK.
OKLA.
IND. TY.
ARIZ.
N. MEX.
TEX.
LA.
FLA.
ME.
MASS.
MEXICO.
GULF OF MEXICO
ATLANTIC OCEAN
PACIFIC O.

ASSOCIATION
OF
ENGINEERING SOCIETIES.
Organized 1881.

VOL. XXIII. DECEMBER, 1899. No. 6.

THE INFLUENCE OF MECHANICAL DRAFT UPON THE ULTIMATE EFFICIENCY OF STEAM BOILERS.

By WALTER B. SNOW, M.E.

[Read before the Boston Society of Civil Engineers, October 18, 1899.*]

A DISCUSSION of the influence of mechanical draft upon the ultimate efficiency of steam boilers may very properly be introduced by a word regarding the apparatus, and a brief description of the methods employed in its production. In its generally accepted form the apparatus consists of a fan blower inclosed in a case and provided with the necessary means for its operation.

The fan wheel itself consists of a number of radial blades carried upon T steel arms cast into the hub. Side plates bind the blades together, and provide two inlets concentric with the shaft; one upon each side of the wheel. The air enters through these inlets and is by the action of centrifugal force delivered tangentially at the tips of the blades, which conform to the outer circumference of the wheel. The air, thus discharged, is, by means of a surrounding case, conducted to an outlet in its circumference.

The volume delivered by a fan is proportional to its speed, while the pressure created varies as the square of the speed, and the power required as the cube of the speed.

Mechanical draft may be applied under either of two general methods, the plenum and the vacuum. Which is to be employed must depend upon the circumstances, for it cannot be asserted that either is unqualifiedly superior under all conditions. As ordinarily applied, under the plenum or forced draft method, the air is forced into the closed ashpit under pressure, and thence finds its escape through the fuel on the grates above. Its success depends largely upon the manner of introduction of the air to the ashpits. For

*Manuscript received November 23, 1899.—Secretary, Ass'n of Eng. Socs.

this purpose a special form of damper is desirable, as shown in Figs. 1 and 2.

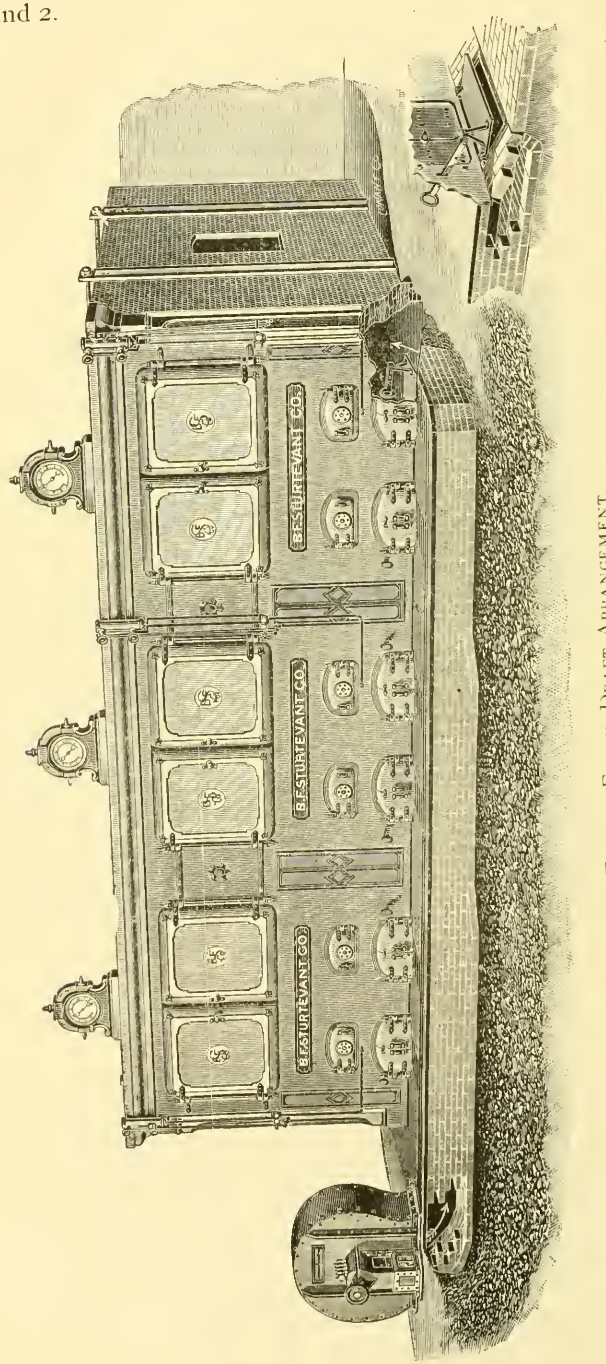


Fig. 1. Forced Draft Arrangement.

In a forced draft installation, as illustrated in Fig. 1, the fan may be so designed that the air is discharged into an underground

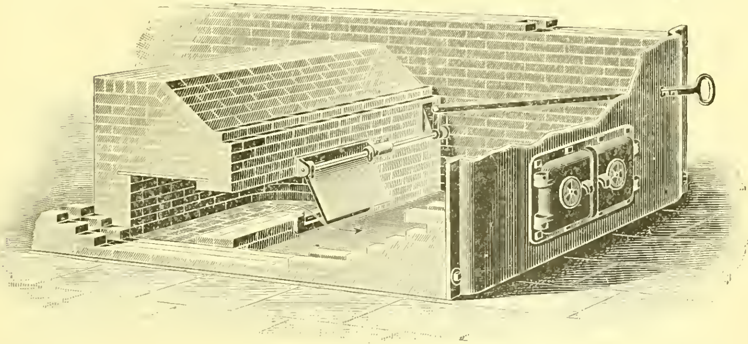


Fig. 2. Ashpit Damper in Bridge Wall.

brick duct, extending along the front of the boilers, whence it passes through branch ducts to the individual dampers in the ashpits.

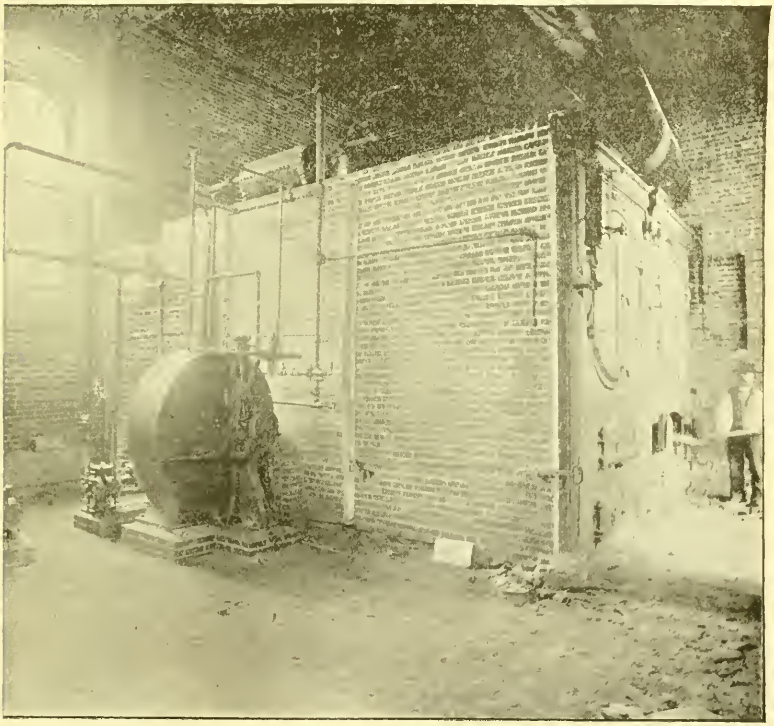


Fig. 3. Forced Draft Plant with Hollow Bridge Wall.

One of these, with its means of operation, is very clearly shown at the right of the cut. Such an arrangement is readily applicable to a boiler plant already installed.

In a new plant, however, the bridge wall may be left hollow and utilized as an air duct, a damper, of the form shown in Fig. 2, being employed and operated from the front by means of the notched handle bar. The effect of both forms of damper is to spread the air evenly over the entire bottom of the ashpit, whence

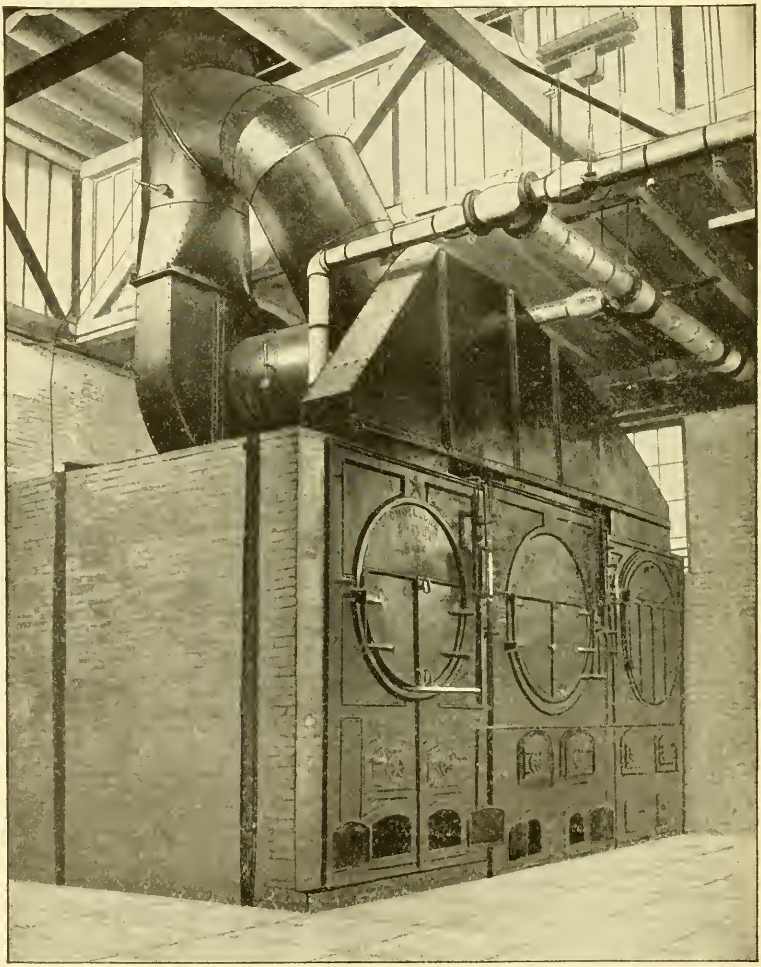


Fig. 4. Induced Draft Plant with Single Fan.

it rises in even volume at low velocity. A plant arranged on the forced draft principle, designed to discharge through a hollow bridge wall, is clearly shown in Fig. 3.

Under the vacuum or induced method, the fan is introduced as a direct substitute for the chimney, creating a vacuum in the furnace and drawing therefrom the gases generated in the process

of combustion. As the draft is thus rendered positive and practically independent of all conditions, except the speed of the fan, it is necessary to provide only a short outlet pipe to carry the gases to a sufficient height to permit of their harmless discharge to the atmosphere.

In practice, the capacity of an induced draft fan must vary with the temperature of the gases it is designed to handle. Therefore the density, which varies inversely as the absolute temperature, should enter as a factor in all such calculations.

Various arrangements of induced draft are usually possible with an ordinary boiler plant. As a rule, the simplest arrangement

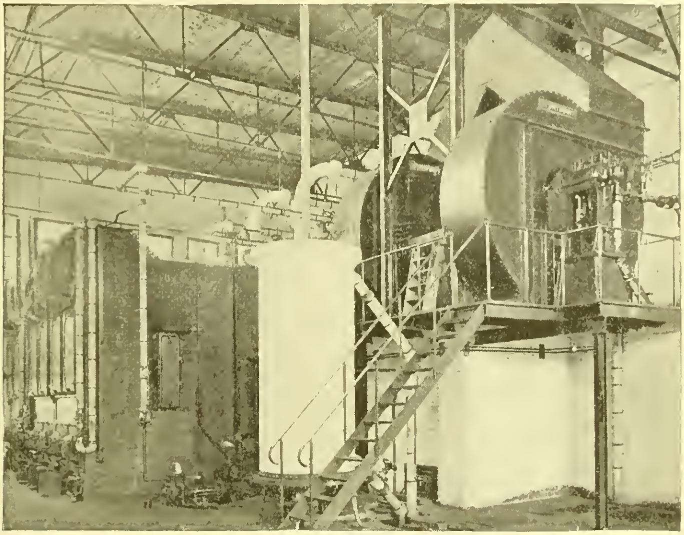


FIG. 5. INDUCED DRAFT PLANT WITH DUPLEX FAN.

consists in placing the fan or fans immediately above the boilers, leading the smoke flue directly to the fan inlet connection, and discharging the gases upward through a short pipe extending just above the boiler house roof.

The arrangement of a single fan after this manner is shown in Fig. 4, while a duplex induced draft plant, having two fans, each of sufficient capacity to produce the required draft for the entire battery of boilers, is presented in Fig. 5. In both instances the fans are provided with direct-connected engines having water-cooled journals.

The ultimate efficiency of a steam boiler is dependent upon three principal factors:

First. The primary cost of the entire plant and the fixed charges thereon.

Second. The quantitative efficiency of the plant as a means of burning the fuel supplied, and transferring its heat to the water evaporated.

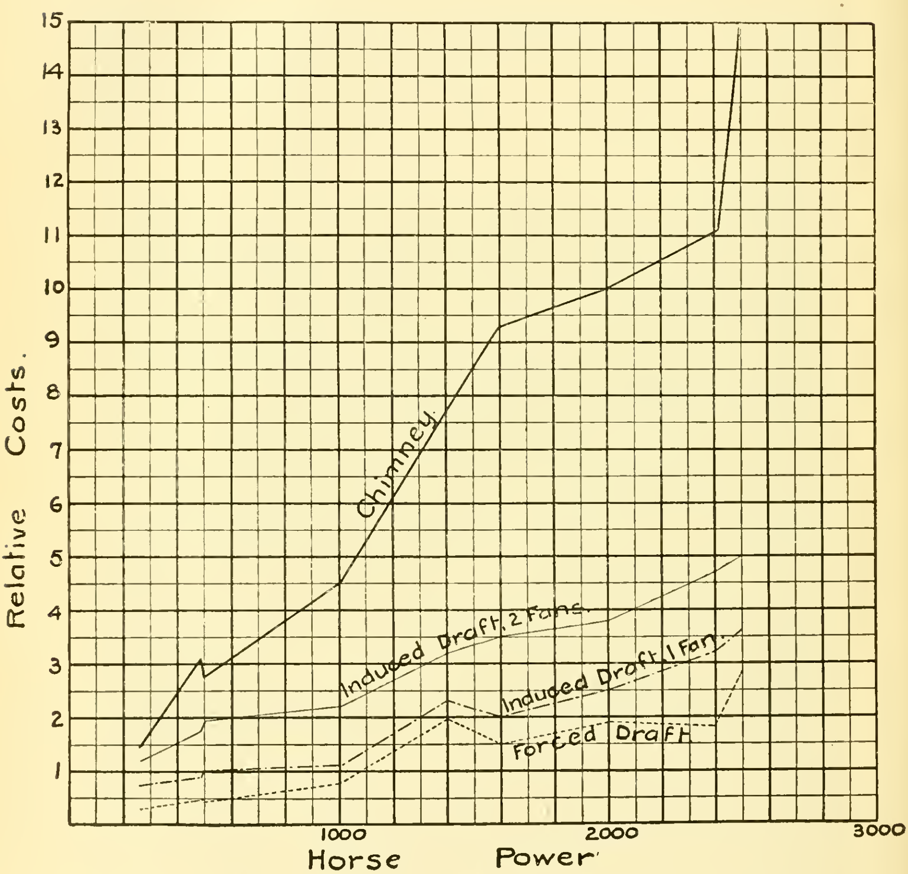


Fig. 6. Comparative Cost of Chimney and Mechanical Draft.

Third. The operating expense including the fuel.

In addition there are always distinct advantages or disadvantages which, while of marked importance, can be measured only qualitatively in their relation to the superiority of any given arrangement or appliance.

In so far as mechanical draft has a direct influence on any of these factors it is the purpose to consider here its ultimate effect upon the efficiency of the steam boiler plant to which it may be applied. Naturally, the question of primary cost first enters into

the consideration, and secondly, that of maintenance and operation, while all three of these items are to be viewed in the light of the efficiency secured. In the matter of first cost comparison is fundamentally made between the cost of a chimney and that of a mechanical draft plant, which may be introduced as a substitute.

In the accompanying curves, Fig. 6, are presented the relative costs of chimneys and of equivalent mechanical draft equipments in a number of boiler plants widely different in character and rated capacity. In certain of these the cost of the existing chimney is known, and that of the complete mechanical draft plant is estimated, while in others the cost of the mechanical draft installation is determined from the contract price, and the expense of a chimney to produce equivalent results is calculated. Costs are shown for both single, forced and induced engine-driven fans, and for duplex engine-driven plants in which either fan may serve as a relay. An apparatus of this latter type is evidently most complete, and is necessarily the most expensive. It finds its greatest use where economizers are employed.

An average for the costs for these nine representative plants shows the total expense for installing a forced draft plant to be only 18.7 per cent., that of a single induced fan and accessories 26.7 per cent., and that of a complete duplex induced draft plant 42 per cent. of that of a chimney. In each case a short steel plate stack is included.

In other words, if a chimney be estimated to cost $10,000, there could be saved, on a basis of these averages, the respective amounts of $8130, $7330 or $5800 in the first cost, according to which system of mechanical draft is substituted.

For a good steam boiler plant it is fair to assume the following as average fixed charges:

Interest	5	per cent.
Depreciation and repairs	4½	"
Insurance and taxes	1½	"
Total	11	per cent.

Experience has shown that these figures also hold good for a well-designed mechanical draft apparatus, and are therefore accepted here. On the other hand the fixed charges on a chimney may be fairly assumed as,—

Interest	5	per cent.
Depreciation and repairs	1½	"
Insurance and taxes	1½	"
Total	8	per cent.

COMPARISON OF COSTS AND FIXED CHARGES.

Method of draft production.	First cost. Amount.	First cost. Ratio.	Annual fixed charges. Amount.	Annual fixed charges. Ratio.
Chimney	$10,000.00	$1.00	$800.00	$1.00
Induced draft plant (2 fans)	4,200.00	.42	462.00	.58
Induced draft plant (1 fan)	2,670.00	.267	294.00	.37
Forced draft plant (1 fan)	1,870.00	.187	206.00	.26

The fact that the mechanical draft apparatus can usually be placed overhead or on top of the boilers where it occupies no valuable space, and that the space otherwise occupied by the chimney is at the same time rendered available, makes possible a further saving which is necessarily dependent upon the land values.

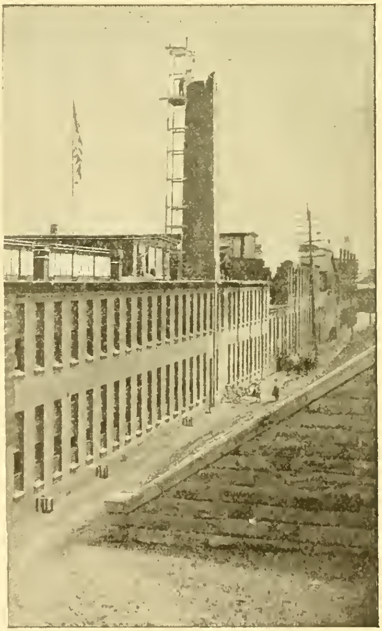


Fig. 7. Showing Smoke Pipe to Right of Chimney.

Within city limits it may readily amount to $1000 in a plant of a thousand horse power.

The relative proportions of a brick chimney and of the smoke pipe required when mechanical draft is introduced are forcibly shown in the accompanying illustrations, Figs. 7 and 8. The removal of the boilers to a position too far distant from the chimney to permit of its longer fulfilling its office naturally presented an excellent opportunity for the substitution of an induced draft fan, and the subsequent removal of the chimney. The present stack or smoke pipe, barely visible in Fig. 8, extends only 31 feet above the ground.

A concrete case illustrating the possibilities of mechanical draft is presented in the accompanying drawings, Figs. 9 and 10. These show a plant of 2400 horse power of modern water-tube boilers, 12 in number, set in pairs and equipped with economizers. The left-hand drawing indicates the location of the chimney 9 feet in internal diameter by 180 feet high, designed to furnish the necessary draft. To the right is the same plant with a complete duplex induced draft apparatus substituted for the chimney and placed above the economizer connections. Each of the two fans is driven by a special engine, direct-connected to the fan shaft, and each is capable of producing draft for the entire plant. A short steel plate

Fig. 8. Showing Smoke Pipe to Right of and Below Flag.

stack unites the two fan outlets and discharges the gases just above the boiler house roof. All of the room necessary for the chimney is saved, and no valuable space is required for the fans.

COST OF BOILER PLANT WITH CHIMNEY.

12 boilers	$37,000.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	9,000.00
Automatic damper regulators and dampers	400.00
Chimneys, including foundations	10,700.00
Boiler house	11,500.00
Total	$79,100.00

RELATIVE COSTS.

Chimney Draft.

Cost of chimney	$10,700.00
Cost of damper regulators and dampers	400.00
	$11,100.00

Mechanical Draft.

Cost of mechanical draft plant complete	4,700.00
Saving by using mechanical draft	6,400.00
	$11,100.00

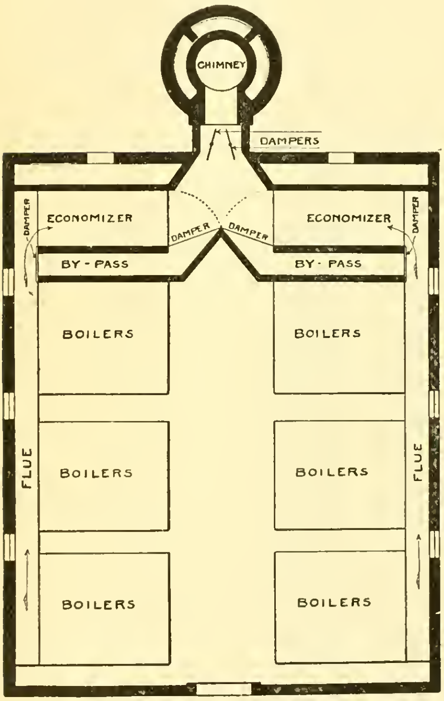


FIG. 9. 2400 H. P. BOILER PLANT OPERATED BY CHIMNEY DRAFT.

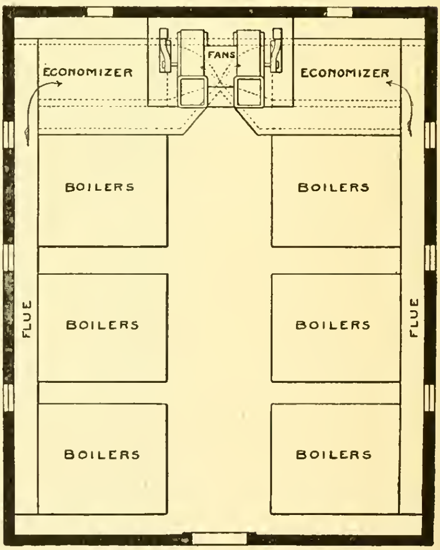


FIG. 10. 2400 H. P. BOILER PLANT OPERATED BY MECHANICAL DRAFT.

The costs of the chimney and the mechanical draft apparatus, which are also indicated, show a saving in first cost of $6400 as the result of using the mechanical draft method.

The intensity of draft produced by a fan and the readiness and economy with which it may be secured make it a simple matter to maintain a combustion rate higher than that ordinarily obtained with a chimney.

The accompanying table, which presents the various pressures, expressed in pounds per square foot, experimentally determined by Professor Gale, for a certain stationary boiler, clearly indicates

that nearly all of the draft is required to overcome resistances incident to the maintenance of a higher rate. Boilers have naturally been proportioned to meet these conditions, but it is manifest that, by changes in design, or by the introduction of heat-abstractors, they may, under the influence of mechanical draft, be readily operated at considerably above their original ratings, with substantially the same efficiency. As a result it is possible to obtain a given output with a plant of less size and first cost than is possible with a chimney. This is particularly true where the steam consumption is liable to sudden fluctuations for comparatively short periods.

FURNACE PRESSURES.

Required to produce entrance velocity (3.6 feet per second)	0.013
Required to overcome resistance of fire grate	0.91
Required to overcome resistance of combustion chamber and boiler tubes	1.23
Required to overcome resistance in horizontal flue	0.06
Required to produce discharge velocity (11.2 feet per second)	0.085
Total effective draft pressure	2.298
Back pressure due to friction in stack	0.19
Total static pressure produced by chimney	2.488

The typical boiler plant already presented will serve as an excellent illustration. Suppose it is determined to omit two of the twelve boilers, say one from each pair at the end farthest from the economizers, and to force the remaining boilers up to the original rating, which can be easily done by mechanical means, as a substitute for the chimney. This will decrease the rating to 2000 horse power, or by $16\frac{2}{3}$ per cent. The volume of air required per pound of coal, with the higher combustion rate, deeper fires and mechanical draft under automatic control, will be somewhat less than that with the chimney, while if the economizers remain the same, their capacity relative to the heating surface of the boilers will be greater, so that the ultimate waste by heat in the escaping gases will certainly not be increased.

RELATIVE COSTS.

2400 Nominal Horse Power Plant, with Chimney Draft.

12 boilers	$37,000.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	9,000.00
Automatic damper regulators and dampers	400.00
Chimney, including foundations	10,700.00
Boiler house	11,500.00
	$79,100.00

2000 Nominal Horse Power Plant, with Mechanical Draft.

10 boilers	$30,833.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	8,500.00
Boiler house	11,000.00
Mechanical draft plant complete	4,700.00
Saving by using mechanical draft	13,567.00
	$79,100.00

The original costs under the two conditions will be about as indicated. A total possible saving of $13,567 is thus shown, of which $7167 is due to the reduction in nominal horse power made possible by the introduction of mechanical draft.

A problem that has to be faced sooner or later in most boiler plants is that of increased capacity. This differs from that just presented in that the chimney already exists, and it becomes a question whether the desired result shall be obtained by forcing the existing boilers or by adding to their number. The former method demands an increase in intensity of draft, which with a given chimney, operating well up to its capacity, can only be obtained by considerable increase of height at excessive expense, while with either method a larger volume of air is required. As a result increased output frequently demands not only more boilers, but a new or higher chimney. Here mechanical draft steps in and presents a simple solution of the problem:

RELATIVE COSTS.

2800 Nominal Horse Power Plant with Chimney Draft.

2 additional boilers	$6,167.00
Settings, etc., for 2 boilers	1,250.00
Addition to building, etc	2,700.00
	$10,117.00

2400 Nominal Horse Power Plant with Mechanical Draft.

Fan, dampers and ducts	$1,500.00
Saving by using mechanical draft	8,617.00
	$10,117.00

Considering the matter of increased output solely in the light of comparative cost between the introduction of more boilers or the introduction of mechanical draft, and disregarding any possible cost of change in the chimney, we may again take for illustration the plant of 2400 rated horse power. Suppose it is desired to increase its capacity to 2800 horse power, or by 16⅔ per cent. Then the relative costs under the two conditions will appear as here indicated.

The saving actually secured by providing surplus capacity in light, rapid-running fans, instead of in ponderous boilers, and the higher efficiency of combustion obtained under proper arrangements with mechanical draft, is most clearly shown by experience in the merchant and naval marine. Here the matter of weight and of space occupied is of great importance. Every pound in weight, or foot of space saved leaves just so much more available for coal and cargo.

We may now turn to that portion of our discussion which relates to the quantitative efficiency of a boiler plant. No greater waste occurs in modern steam-boiler practice than that which is inherent in the employment of a chimney for the production of draft,—namely, the loss of heat in the escaping gases. As the chimney depends for its action upon the maintenance of a temperature difference between the internal gases and the external air, it is manifest that with a chimney this waste can never be eliminated. It may be palliated, it is true, by the building of higher chimneys, so that the same intensity of draft may be obtained with a lower stack temperature. But such means of providing for the utilization of the otherwise waste heat is expensive. For instance, if, with an external temperature of 60°, and an internal temperature of 500°, sufficient intensity of draft is produced by a chimney 100 feet high, it will require a height of 175 feet to produce the same draft when the temperature of the gases is reduced to 250°. In addition the means provided for extracting this heat will increase the resistance, and provisions for overcoming the same will have to be made by greater chimney height.

In the case of a fan, however, the power expended as measured in heat units necessary to produce the same results may, under ordinary conditions, be only about one-seventy-fifth of that necessary with a chimney. In other words, the fan renders available for utilization practically all of the heat wasted by the chimney, while it possesses the further advantage of readily creating the additional draft requisite when heat-abstracting devices are introduced.

Messrs. Donkin & Kennedy in seventeen independent boiler tests found the heat lost up the stack when no economizer was used to range between 9.4 per cent. and 31.8 per cent. of the total heat of combustion. As it is not practicable to cool the gases to atmospheric temperature, it is evidently impossible to utilize all of the heat, but the ordinary economizer should, with mechanical draft, show a saving of between 10 and 20 per cent.

The average results obtained by Roney from tests of nine plants equipped with economizers and mechanical draft were as follows:

Temperature of gases entering economizer	526.3	degrees.
Temperature of gases leaving economizer	269.6	"
Decrease in temperature of gases	256.7	"
Temperature of water entering economizer	150.4	"
Temperature of water leaving economizer	297.1	"
Increase in temperature of water	146.7	"
Fuel saving in per cent		14.64

Although not developed to the same extent as the economizer, the air heater, by which the heat is transferred from the gases to the air supplied to the furnace, has been introduced to a considerable extent with satisfactory results. In experiments with the Marland

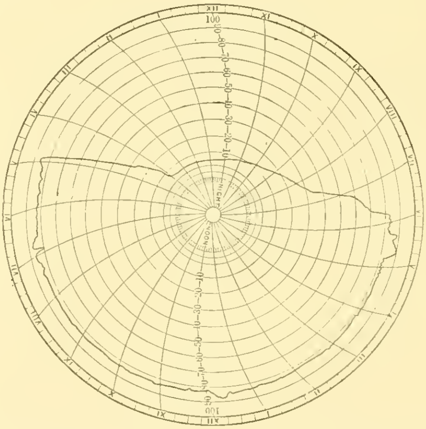


Fig. 11. Steam Pressure Chart for Induced Draft Plant.

apparatus Hoadley showed that the waste of the flue gases could be reduced to only 5 per cent. of the total heat value of the fuel with an accompanying expenditure of only 1 per cent. of the steam generated for driving the blower.

The importance of mechanical draft in the adoption of means for utilizing the waste heat is well exemplified in the introduction of retarders and of ribbed tubes. Both of these increase the resistance, and almost invariably require fan draft to enable them to create the saving of 5 to 10 per cent. which may be thus secured.

The facility with which the intensity of the draft and the volume of air supplied can be regulated when a fan is employed for draft production has always been recognized as one of the most valuable characteristics of this method. Such regulation makes possible the most perfect distribution of the air, and its reduction

to the minimum amount which will produce satisfactory combustion.

Variable draft is necessary to maintain a constant steam pressure. This is evidenced by the accompanying charts from a mechanical draft plant. Fig. 11 illustrates the practical uniformity of steam pressure maintained, while Fig. 12 indicates the considerable fluctuations of the draft required. The operation of the fan is automatically regulated so that the slightest variation in the steam pressure causes considerable change in the speed, and consequently in the draft.

For the mere chemical requirements of the combustion of one pound of ordinary coal, about 12 pounds or 150 cubic feet of air is required. But under the conditions of chimney draft this amount is greatly exceeded. Donkin & Kennedy showed in the results

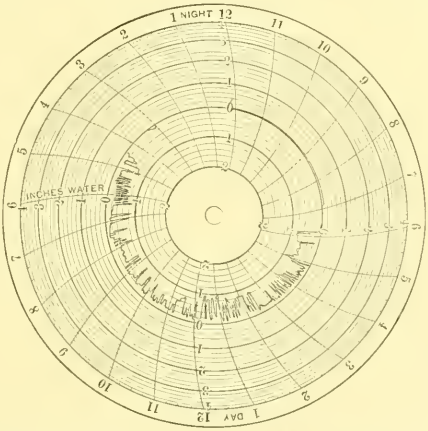


FIG. 12. DRAFT PRESSURE CHART FROM INDUCED DRAFT PLANT.

of sixteen tests that the air supply ranged from 16.1 pounds to 40.7 pounds.

The theoretical effects of an excess of air upon the combustion of an ordinary anthracite coal are such that the ideal temperature in the heart of the fire decreases with the excess, while the relative weight of the products of combustion becomes greater. Although the initial volume increases with the excess it is to be noted that the relative volume, after heating, remains practically constant because of its lower temperature and consequent greater density. As the gases pass onward through the tubes they become cooled, but those of higher temperature part most readily with their heat, and at the same time their volume and consequent velocity are reduced, still further facilitating heat transmission. On the other hand, the gases of lower initial temperature transmit their heat less

rapidly, and the final result is that within practical limits the temperature of the escaping gases is highest with the greatest excess of the air supply.

The fact just presented points toward the economy to be secured by comparatively high rates of combustion when the proper rate of heating surface to grate surface is provided. A high combustion rate manifestly requires a thicker fire, which in turn presents a better opportunity for contact between fuel and air with consequent economy in the supply of the latter. Less air results in a more intense fire, a higher furnace temperature, a greater transmission of heat to the water within the boiler, and a resultant higher evaporative efficiency. But the thicker fire requires a greater intensity of draft to overcome the increased resistance, while the relatively smaller area for passage of air necessitates a higher velocity of that air, and, furthermore, the increased intensity to produce this velocity must be proportional to the square of the rate of flow. This condition is most readily met by the fan, which, under normal conditions, produces an intensity exceeding that of an ordinary chimney, and which can, without trouble, maintain the highest practicable rate of combustion.

Whitham found that with a certain mechanical stoker in which the air distribution was almost ideal, an excess of 85.6 per cent. was used when the rate of combustion was 12 pounds, while almost perfect evaporative efficiency was maintained when the rate was 45.4 pounds, and the air supply actually 11.2 per cent. below the chemical requirements.

The actual fuel saving resulting from the introduction of mechanical draft is forcibly shown by the accompanying record of eight voyages of the same vessel under identical conditions, except as regards the means of draft production. It is to be noted that the total consumption of coal per day was reduced 13 per cent., while the time occupied in making the voyage was decreased nearly 5 per cent. by the substitution of forced draft.

SAVING BY FORCED DRAFT ON STEAMSHIP "DANIA."

Conditions.	Days steaming.	Knots per hour.	Consumption of coal per day.	Consumption for all purposes per day steaming.
Natural draft, 4 voyages........	17.00	7.50	9.73	10.70
Forced draft, 4 voyages.......	16.21	7.58	7.76	9.31

Among the losses incident to combustion, that resulting from the formation of smoke is absolute, for it is equivalent to directly robbing the fire of a part of the fuel from which not only has no heating effect been secured, but upon which heat has actually been wasted in raising it to the temperature of the escaping flue gases.

Fortunately from a purely economic standpoint, this loss seldom, if ever, exceeds 1 per cent. of the total calorific value of the fuel. In fact the prevention of smoke is not to be considered so much in its economic aspect as in its relation to the stringent laws which are being enforced in many communities. It thus becomes a question of life or death, for, unless the smoke is prevented, the boilers cannot be operated. For the prevention of smoke, sharp, intense draft is necessary, properly regulated and capable of furnishing the required amount of air, both below and above the fuel at the very moment when it is most needed. This result can be best secured by the introduction of mechanical draft, which is ordinarily so regulated that the decrease in steam pressure resulting from the opening of the fire doors, the charging of the furnace or the clearing of the fires instantly causes an increase of the speed of the fan and in the intensity of the draft and the volume of air.

A loss incidental to poor draft is that due to the formation of carbonic oxide. The formation of this gas instead of the complete product of combustion, carbonic acid, results from the lack of air, and may under adverse conditions mount up to a resultant loss of 5 or 10 per cent. and over of the calorific value of the coal. Thick fires and large charges of cold fuel are certainly not conducive to the ready flow of air under only slight pressure, such as is maintained with the chimney. Under these conditions any operation of the flue damper, automatic or otherwise, only serves to vary the volume of the air, but in no way increases the intensity of the draft. This can only be secured by some means like the fan, which under automatic regulation increases both the intensity of the draft and the volume of the air when required. As a result, the pressure forces the air in sufficient quantity to all spaces between the fuel, and renders the combustion practically perfect. Numerous tests of the flue gases fail to reveal the presence of any carbonic oxide when mechanical draft is employed.

By far the most important of the factors connected with the operating expense of a boiler plant is the cost of the fuel. When burned under suitable conditions, the decrease in its cost far outstrips the decrease in its efficiency, so that the solution of the problem involves itself with the provision of the proper conditions. As a rule the cheap fuels, like the fine anthracites, require for their combustion an intensity of draft, which the ordinary chimney is incapable of producing. Speaking of the chimney in this connection, Coxe asserted that "It is always very difficult, in fact almost impossible, to obtain with it sufficient blast to burn the smallest sizes of anthracite coal, which require a strong and concentrated draft."

It is here that mechanical draft presents itself as a solution, for it fully meets the most exacting requirements as regards intensity, costs far less for its installation than a chimney of equivalent capacity, and is capable at all times of producing the blast necessary for securing the best results in the furnace.

What these requirements are is evidenced by the accompanying figures from careful tests by Coxe:

RESULTS OF TESTS OF PEA AND BUCKWHEAT COALS.

Kind of coal.	Rate of combustion per sq. foot of grate per hour.	Pounds of water evaporated from and at 212° per lb. of coal.	Air pressure in inches of water.	Maximum limit to size of coal in inches.
Oneida pea coal	13.63	8.56	0.375	7/8
" No. 1 Buckwheat	13.58	7.94	0.5	9/16
" No. 2 "	11.40	8.60	0.625	3/8
" No. 3 "	11.34	8.65	1.04	3/8
Eckley No. 3 "	9.44	8.75	1.125	3/16

These coals, which are among the smallest in size, were burned on a special form of traveling grate, and the air pressure was maintained in the chamber beneath. It is noticeable that with practically constant combustion rate and evaporative efficiency the draft increases very rapidly as the size of the coal decreases.

RELATIVE EFFICIENCIES OF VARIOUS COALS.

Kind of coal.	Water evaporated from and at 212° by 1 lb. of dry coal.	Relative efficiency in per cent. Cumberland = 100.	Cost of coal per ton.	Fuel cost of evaporating 1000 lbs. of water from and at 212°.	Relative efficiency in per cent. measured by cost to evaporate 1000 lbs. Cumberland = 100.
Cumberland	11.04	100	$3.75	$0.1698	100
Anthracite, broken	9.79	89	4.50	0.2297	74
Anthracite, chestnut	9.40	85	5.00	0.2660	64
Two parts pea and dust and one part Cumberland	9.38	85	2.58	0.1375	123
Two parts pea and dust and one part culm	9.01	82	2.58	0.1432	119
Anthracite pea	8.86	80	4.00	0.2259	75
Nova Scotia culm	8.42	76	2.00	0.1187	156

The comparative efficiency of various coals as determined by Barrus is indicated in the accompanying table, which speaks for itself. The evidence in favor of burning low-grade fuels is conclusive. Such results can, however, only be secured by positive and intense draft.

It is true that as the quality of the coal grows poorer and the size of the particles less, it becomes more necessary to provide some special form of grate or stoker for its proper burning. But

even without an economizer to utilize the waste heat, the burning of cheap fuel by mechanical draft will, under perfect conditions, show a decided saving after due allowance is made for fixed charges on the special furnace arrangements, and for the cost of operating the fan:

ANNUAL SAVINGS RESULTING FROM BURNING CHEAP FUEL, IN 1000 H. P. PLANT.

Water evaporated from and at 212° per lb. of coal.	COST PER TON.														
	$0.50	$0.75	$1.00	$1.25	$1.50	$1.75	$2.00	$2.25	$2 50	$2.75	$3 00	$3.25	$3.50	$3.75	$4.00
11.00	....	....	....	....	....	....	....	....	....	....	4,892	3,669	2,446	1,223	....
10.50	....	....	....	....	....	....	....	....	....	5,474	4,193	2,912	1,630	349	....
10.00	....	....	....	....	....	....	....	....	6,115	4,770	3,424	2 079	734	....	....
9 50	....	....	....	....	....	....	8,240	6,823	5.407	3,991	2,575	1,159	....	....	....
9 00	....	....	....	....	....	9,105	7,610	6,115	4,621	3,126	631	136	....	....	....
8.50	....	....	....	....	10,074	8,491	6,909	5.326	3,743	2,160	578	....	....	....	....
8.00	....	....	....	11,180	9,478	7,797	6,115	4,433	2.752	1,070	....	....	....	....	....
7.50	....	....	12,393	10,599	8,805	7,012	5,218	3,424	1 630	....	....	....	....	....	....
7.00	15,724	13,803	11,881	9,959	8,037	6,115	4,193	2,272	350	....	....	....	....	....	....

The possible savings with low-grade fuels and mechanical draft are still further evidenced by the accompanying table, which shows, for a 1000 horse power plant, the annual saving, based on 312 days of ten hours each, which would result from the substitu-

tion of a cheaper fuel for, say Cumberland coal, costing in round figures $4 per ton, and evaporating eleven pounds of water from and at 212° per pound of coal. Under these conditions the annual fuel expense would be $19,568. If the assumption be made that a coal costing $2.50, and evaporating only nine pounds of water, is substituted, the annual saving would be $4621. The fuel cost of operating the fan, even if the exhaust steam was not utilized and it required $1\frac{1}{2}$ per cent. of the total coal burned, would be only $224, and if this is charged against the saving it would still amount to $4397, a sum sufficient to show a most creditable reduction in operating expense even if there was charged against it any additional labor and the fixed charges on a complete equipment of the special appliances for burning the lower grade fuel. In general practice a mere change of grate bars is sufficient to adapt a boiler for burning almost clear yard screenings by means of mechanical draft.

A reduction of over $125 per week, equivalent to $6500 per year, has been made in actual practice in the case of a boiler plant of 1000 horse power by the introduction of mechanical draft and the burning of yard screenings with a slight mixture of Cumberland.

A very interesting example of the reduction of fuel cost incident to the introduction of mechanical draft here follows. The average load for the second year exceeded by about 30 horse power that of the first year:

RESULTS OF OPERATION OF BOILER PLANT AT HOTEL IROQUOIS, BUFFALO, N. Y.

Without Mechanical Draft.

Time.	Kind of coal.	No. of tons.	Cost per ton.	Total cost of each kind of coal.	Weight and total cost of coal for year.
Dec. 1, 1892, to Nov. 30, 1893.	Hard Coal Screenings	232	$1.25	$1072.45	4751.24 tons.
	Hard Coal Screenings	601.9	1.30		
	Soft Nut	696.95	2.20	$9084.92	$10,157.38.
	Soft Nut	15.04	2.25		
	Soft Nut	1,759.6	2.30		
	Soft Nut	1,445.75	2.40		

With Mechanical Draft.

Time.	Kind of coal.	No. of tons.	Cost per ton.	Total cost of each kind of coal.	Weight and total cost of coal for year.
Dec. 1, 1893, to Nov. 30, 1894.	Hard Coal Screenings	1,299.95	$1.30	$5356.24	5013 tons.
	Hard Coal Screenings	2,610.08	1.40		
	Hard Nut	3.02	3.50	$2333.69	$7680.93.
	Soft Nut	843.03	2.10		
	Soft Nut	255.9	2.20		

Although the annual coal consumption was increased as was to be expected with the lower grade of fuel, yet a reduction of nearly 25 per cent. in the cost was effected.

With the increasing interest in the possible reductions in operating expenses, more attention is being turned to the mechanical stoker, both as a means of more economically and of more uniformly supplying the fuel to the furnace. As incidental to its success, positive and automatically regulated draft is a necessity. This is particularly true in the case of the modern forms of under feed and chain feed machines. The forced method of mechanical draft is generally employed and the necessary arrangements are of the simplest character.

Of the advantages of mechanical draft which are purely qualitative in their character much might be said, but time will not permit. It must suffice to merely refer to the more prominent points of advantage.

When the fan is employed for draft production the steel plate construction, the comparative lightness, the portable character and the absence of heavy foundations render extremely simple its adaptation to the exact requirements. Being portable it is also salable, and hence an asset of real value as compared with the chimney. It may be used either for forced or induced draft and placed where it will occupy no valuable space. It may be operated by direct connected or belted engine or motor, and so proportioned as to produce any desired draft pressure.

In operation the fan is both positive and flexible, independent of the weather, but capable of regulation to the finest degree and of adjustment to the necessities of the fire at any particular moment. A mere increase in the cut-off of the fan engine brings about a result only secured with a chimney at the expense of adding to its height, while a change in the fan speed alters both the volume handled and the intensity of the draft produced.

If this discussion of the influence of mechanical draft on boiler efficiency has rendered clear the factors concerned, it has with equal force shown that this influence is beneficial,—in many ways markedly so. In the light of this fact the present active interest in the subject points to the future consideration of mechanical draft as a most important factor in steam boiler practice.

WATER WASTE.

By Joseph C. Beardsley, Member Civil Engineers' Club of Cleveland

[Read before the Club, June 13, 1899.*]

Water waste, while it is one of the most annoying difficulties with which the water works engineer comes in contact, can scarcely be considered an engineering problem, for the reason that the solution of it is perfectly obvious and the means of preventing it easily available, providing only that the administrative officers are sufficiently broad-minded and intelligent to appreciate the situation. It is essentially an administrative rather than an engineering question, and the only reason for presenting such a subject to an audience of engineers is that it usually falls to engineers to educate the administrative officers up to the point of applying the one infallible remedy and the water takers to accepting it as the only just means of estimating their water rates.

Cleveland was fortunate in this respect, and meters have been in service here for considerably over twenty years without serious objection from either administrative officers or water takers.

According to American ideas, air and water are on about the same plane,—the supply of each should be equally free and limited only by the demand, no matter of what nature,—and this idea was perfectly proper fifty years ago, when every man had his own well or running stream from which to draw his supply, which was usually limited only by his physical ability in drawing it. Even then, however, no man drew water from his well for the pleasure to be derived from spilling it on the ground.

Now, with the development of the modern city, we have all this "drawing of water" accomplished for us, and instead of expending physical effort we pay for it in cash.

We are able to have a supply at any point we desire it, and it comes with the simple turning of a cock; but with all this ease of accomplishment comes the idea that it is not incumbent on us to use any discretion in the consumption of what comes to us so easily.

This idea is fostered, too, by the manner in which payment is made, in the great majority of cases, for this service. When one has to pay only a certain fixed rate, based on the number of rooms or fixtures, it is easy to fall into the habit of thinking that it really makes but little difference how much water is consumed and to

*Manuscript received December 6, 1899.—Secretary, Ass'n of Eng. Socs.

procrastinate going for the plumber if any of the fixtures get out of order and run continuously.

If any qualms of conscience do make themselves felt, we reason that our neighbor is probably doing the same thing anyway, and ask ourselves why shouldn't we? or, again, somewhat contradictorily, we feel that "just our one faucet running don't waste much water." We should stop the leak very quickly, however, if the supply depended on our own physical exertions, or if we had to pay for it according to the amount we consumed.

The operating expenses of the Cleveland Water Works for the year 1897 were $182,694.22.

The total cost of the plant, including that year, was about $8,500,000, the interest on which, at 5 per cent., which would be a fair average for the period covered, would be $425,000, making a total of $607,694.22. The total water pumped during 1897 was 17,658,470,308 gallons.

This makes the cost of furnishing water about 3.4 cents per 1000 gallons, and in these figures no allowance is made for the cost of pipe extension, river tunnels and other minor construction which is paid for out of the income without the issue of bonds.

This shows that while water is a cheap commodity, it still does cost something, and it is perfectly apparent, since the expenses are nearly proportional to the amount of water pumped, that water rates can be reduced only by reducing the amount of water pumped, or by cutting off all the improvements that are paid for out of the revenue.

In Cleveland the minimum water rate with a private meter (one set at the expense of the consumer) allows a consumption of 150,000 gallons at a cost of $8.00 per year.

These meters are set almost invariably on dwellings, and form a fair basis of estimate of the necessities of a family. At this rate each service would consume 410 gallons per day, and, estimating six consumers to a service, would allow a per capita consumption of 68 gallons per day. This would seem to be a liberal allowance, and experience has shown that the consumption on private meters seldom reaches this rate. In the few cases where it is exceeded it is almost invariably found that there has been a leak or some unusual condition of consumption. Dwellings where private meters are in service would pay by assessment from $12.00 to $20.00 or more, and under present conditions this rate cannot be reduced without creating a deficit in the revenues of the department.

An expert commission appointed in the city of London to investigate the subject of water supply estimated that 42 gallons per

capita per day was a liberal supply, and in Paris the actual consumption is 36 gallons. In Cleveland the consumption in 1897 was 136.3 gallons per capita per day, which was the highest in the history of the city except for 1895, when it was 136.6 gallons; 24.4 per cent. of the total pumpage for 1897 was metered, and this may fairly be taken to represent the amount of water consumed for manufacturing and other similar purposes. Deducting this from the average for 1897 leaves 103 gallons on the unmetered services. Assuming our minimum private meter rate as a fair estimate of a liberal supply (68 gallons), this would leave 35 gallons, or 34 per cent. of all water not metered; and, of course, the showing would be much worse if we were to take the London or Paris figures, or even those of the actual consumption on our private meters. This cannot all be assumed to be waste, for we furnish a large amount of free water for municipal and charitable institutions, to say nothing of flushing paved streets and sewers and puddling trenches; but a large proportion of it is undoubtedly waste.

In many other cities the showing is much worse, notably in Philadelphia, where our friend Mr. Trautwine has been making a valiant, but so far, I believe, unsuccessful, fight for the introduction of meters.

In a paper read by him before the Engineers' Club of Philadelphia, in October, 1898, some startling figures are given. In one district of Philadelphia, containing 142 modern seven-room houses, with 539 inhabitants and 782 water appliances, 22 of these appliances were found leaking slightly and 32 were found running continuously.

The water consumed in this district during twenty-four hours was 119,800 gallons, or 222 gallons per capita per day, of which he estimates that only 16,120 gallons, or 13.4 per cent., was used, the remaining 86.6 per cent. being wasted. The figures for water used look rather small, as they allow only about 30 gallons per capita per day; but in any event it is easy to see that a large proportion of the water furnished to this district was wasted.

In another district a similar examination showed that 63 per cent. of all the water furnished to it was wasted.

The average daily consumption in Philadelphia has risen from 36 gallons per capita in 1860 to 215 gallons in 1897. Practically no meters are in service there.

In Cleveland the average daily consumption has risen from 7.75 gallons per capita in 1857 to 136.3 gallons in 1897, the increase being practically continuous from year to year.

Following is the daily per capita consumption in 1890 of several cities:

Allegheny, 238 gallons, with no meters in service; Buffalo, 186 gallons, with .02 per cent. of taps metered; Richmond, 167 gallons, with 1.4 per cent. of taps metered; Detroit, 161 gallons, with 2.1 per cent. of taps metered. Milwaukee commenced in 1875 with an average consumption of about 3,000,000 gallons per day, reached a maximum of 35,000,000 gallons per day in 1894 and has since declined, the maximum in 1897 being a little over 26,500,000 gallons per day, an average of 88 per capita. This was for the single month of July, and the average for the year is only 79 gallons per capita per day. Meters have been in very general use in Milwaukee since about 1890, and in 1897 there were 20,000 in use, which I should estimate to include at least 50 per cent. of all taps. It is noticeable in the foregoing instances how the daily average decreases as the number of meters increases.

A still more striking illustration of the effect of the introduction of meters is furnished by the experience of Detroit. From 1870 to 1888 the consumption increased from 64 gallons per capita per day to 204 during the latter year. During 1888 the setting of meters was commenced, and it has been since steadily continued, until in 1898 there were 5393 in service on 10 per cent. of the taps, and including 20 per cent. of the consumption. Since 1888 the consumption per capita per day has varied between 172 gallons in 1889 and 124.5 gallons in 1897. If the meters had not been set it is safe to assume that the increase in consumption would have risen at the rate that prevailed at the time of the setting of the meters. If this had been the case, it would have been necessary to make additions to the plant that would have involved an expenditure of $600,000 and an increase in operating expenses of $11,000 per year.

The meters are read and kept in repair without noticeable increase in the operating expenses, and they cost only $151,000.

I might go on indefinitely to cite such examples, but enough has been said, I think, to show that in cities where meters are not generally in use there is a rapidly increasing consumption of water, which is largely pure waste, and which involves large additional expenditures every year for plant and operation, while there is no such increase in cities where meters are in general use.

It may be of advantage now to inquire into the manner in which this waste occurs.

Quoting again from Mr. Trautwine's paper, a faucet leaking one drop per second wastes 5 gallons daily; one dropping constantly, but not running a continuous stream, 9 gallons; a third,

running the smallest possible steady stream, 14 gallons, and so on up to one running full opening, 2357 gallons in twenty-four hours.

To come to more concrete examples, we had occasion some years since to meter a number of church schools where there were flagrant wastes of water. On one of these the assessment was $10.00 per year. In ten days the meter had registered 14,500 cubic feet, and if this rate had been continued the bill would have been $208.80 for one year. Notices and warnings had been served repeatedly on the school authorities, but it was not until the meter was set that any serious effort was made to put a stop to the waste. During this metering of the church schools, however, some political toes must have got trodden upon, for we got an order that no more meters must be set without the express sanction of the Mayor. Fortunately the worst offenders had been metered by that time.

A more recent case occurred last month on Merwin street. A foreman had been sent to set a meter for a new manufacturing concern, and by mistake, there being two connections in front of the place, got the meter on the connection for the place next door.

As it was in a district which it is desired to meter generally, no great harm was done, and the meter was allowed to remain. Next day the foreman went to set the other meter, and incidentally took a reading of the first one, finding a consumption of over 1000 cubic feet in less than twenty-four hours. The assessment rate on this place was $7.00 per year. The meter rate at the rate of consumption for the first day would have been $146, but an investigation revealed a water closet that was running constantly and it was immediately shut off.

Still another case was found in a peculiar way. A main was being laid in a certain street, and in the course of operations it became necessary to cut through a sewer connection coming from a saloon. A constant stream of water was found running in the sewer, and the saloonkeeper claimed to be totally unable to put a stop to it.

The flow was finally stopped by shutting off the water connection for the place.

This was thought to be a favorable location for a meter, and one was accordingly set.

The reading of the meter three days after it had been set was 3310 cubic feet, and the meter was going constantly. The assessment rate on this place was $30.50 per year. The meter rate, unless the waste is stopped, will be about $160.

If the annual diagram of daily consumption for a large city is studied in connection with the daily changes of temperature, it will

be observed that the pumpage runs up with extreme high temperature and also with extremely low temperatures. During periods of extreme cold the waste is due, of course, to the practice of allowing the water to run to keep it from freezing. With the high temperatures the increase is due to excessive sprinkling, to the very general tendency to allow the water to run until it becomes cool for drinking and to the practice of using the water in lieu of ice for cooling purposes. One summer not long since the owner of several large tenement buildings was notified that the consumption on one of his buildings was running to quite an unusual figure, and he desired us to investigate the cause of it. We did so, and found six out of about thirty tenants using their bathtubs as refrigerators. Perishable provisions were put in closed vessels, and then the water was allowed to run constantly over them to keep them cool. All other fixtures in the building had self-closing cocks, so the bathtubs had perforce to be utilized.

Cleveland is not by any means one of the most generally metered cities in the country, but that meters have been set with a consistent regard for measuring the large consumers is shown by the fact that with only about 4 per cent. of the taps metered 24.4 per cent. of the entire pumpage is measured; and the policy at present is to continue, steadily if not rapidly, to place meters in the older sections of the city, where the plumbing is most apt to be defective and where experience has taught us that there is the greatest unnecessary waste of water.

DISCUSSION.

C. O. Palmer.—What is the life of those meters?

J. C. Beardsley.—We figure this by work done by the meter rather than by time. For a ¾-inch meter, the smallest size used by us, we have taken 1,000,000 cubic feet, but I think this too high. For a 4-inch meter 40,000,000 cubic feet has been our standard, but I am of the opinion that this is too low for a Worthington meter.

C. S. Howe.—What is the accuracy of the meters?

J. C. Beardsley.—Meters are required to register within about 1 per cent. when new; after wear they register less. The first cost of the meter is from $15.00 to $20.00 (depending on the kind) for a ¾-inch meter, and the cost of setting is about $15.00. When set at the consumer's expense he pays 40 cents per 1000 cubic feet of water, with a minimum charge of $8.00 per year. Private meters may be set in basements, and the cost of this is seldom over $5.00.

C. O. Palmer.—How often are the meters replaced?

J. C. Beardsley.—They are left in until they register the

amount we have estimated to be the limit for each size, unless there are other reasons for changing.

M. W. Kingsley.—Many kinds of meters have been tested as to durability; a Worthington $\frac{3}{4}$-inch meter was run to 3,000,000 cubic feet, with tests as to accuracy every 100,000 cubic feet. When it had registered 1,000,000 cubic feet it was within 8 per cent. of accuracy.

Robt. Hoffman.—How are they tested as to accuracy?

J. C. Beardsley.—By running water from meter into a graduated tank in different-sized streams from 1-16-inch to full size of the meter.

A. A. Skeels.—Does the meter affect the pressure?

J. C. Beardsley.—Very little.

John C. Trautwine, Jr. (correspondence).—Touching the statement in my paper presented to the Engineers' Club of this city October 1, 1898, that in the district mentioned only thirty gallons per capita per day were really used, Mr. Beardsley refers to this estimate as looking "rather small," and it is therefore proper to state how the estimate was formed. The measurement of the consumption of the district was made by means of the Deacon waste water detector (described in Proceedings Institution of Civil Engineers, London, Vol. XLII, 1874-5, and in Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897), which gives a continuous graphic record of the consumption. As the district examined contained only small dwelling houses, "the quantity running during the night (say from midnight to 2 or 3 A.M.), as detected by the Deacon meter, was considered as wasted, and it was assumed that during the day the waste went on at the same rate." (Mr. Allen J. Fuller, assistant in charge of distribution, in report of Bureau of Water, Philadelphia, for 1895, page 196.) The waste thus estimated amounted to 192 gallons per capita per day, leaving out of the total of *222* gallons only 30 gallons for "use". That this estimate is probably not much too low is indicated by the fact that meter observations continued for more than three years on a suburban dwelling with lawn, and occupied by a family of eight persons; keeping one horse, showed an average daily per capita consumption of only 34½ gallons. In this case the payments were by schedule rates, the meter being used only for the purpose of gaining information.

Noting Mr. Beardsley's remark that "practically no meters are in service" here, it may be well to state that at the close of 1898 1481 meters were in use, but these were all on manufacturing establishments or other large consumers, Councils not permitting the adjustment of water rent on dwellings by meter.

GRADE CROSSINGS.

By Augustus Mordecai, Member Engineers' Club of Cleveland.

[Read before the Club, December 26, 1899.*]

In the discussion of the question of eliminating grade crossings of highways with railroads we must be careful to avoid prejudice. It is hard to overcome the natural impulse to make the corporation bear as much of the burden as possible, whether it is right or wrong to do so. "The corporation can afford it," we say. It is hard even for an employe to divest himself of this feeling, and still more so for one not so employed. Often we notice an employe throwing away as worthless a bolt, for example, that has lost a nut; but if the bolt belongs to his bicycle, how carefully he preserves it for future use.

Even to the most wealthy, the expenditure of millions of dollars must be a matter of careful and judicious thought, not lightly to be entered into.

Let us see what are the rights of the parties, the public and the railroads, in the highway. They are equal as far as occupancy is concerned, and both can go their ways, provided that in so doing neither interferes unreasonably with the other. All are obliged to use caution in the use of the common highway. The individual must be careful he does not take any unnecessary chances in crossing the tracks of the railroad. The electric company, if there is one, must see that its conductor knows that the way is clear before he allows its car to cross; and the railroad company must, by watchmen and gates, or by bell and whistle, warn the public, and use every precaution to have the way clear before its train crosses the highway. Neither of the parties must obstruct the crossing for an unreasonable length of time, consequently all would be benefited equally by the elimination of the grade crossing if it were not for certain conditions not common to both. By the abolition of the grade crossing the public saves time, annoyance due to delays or to precautions necessary for the prevention of accident, and damage caused by the accident itself. A very large proportion of accidents (judging from the records of the Erie Railroad, as high as 60 per cent.) is due to the contributory negligence of the individual. The street car company saves time—not a large item, as the man are paid by the trip—and the liability of accident, which is a much more important consideration with them than with the steam railroad, as its car is weaker and the passenger much more liable to injury.

*Manuscript received December 30, 1899.—Secretary, Ass'n of Eng. Socs.

The steam railroad saves the expense incident to watching the crossing, an expense which legally, but perhaps not justly, it is forced exclusively to bear; the time which would be lost in taking precaution against accident (a larger item than in the case of an electric railroad, as the steam road generally has many highways to cross) and the liability of injury in case of accident, which, as shown, is lower in the case of the steam railroad than with the electric road or with the public. The laws of New York make it obligatory on the part of the parties interested to abolish the crossing if the Board of Railroad Commissioners says it should be abolished; the railroad company paying one-half, the city or village one-quarter and the state one-quarter of the cost. In Ohio, if the railroad company and the municipal authorities agree that the crossing may be abolished, not more than 35 per cent. of the cost is paid by the municipality and not less than 65 per cent. by the railroad company. This is certainly not burdensome on the municipality, especially when we remember that the railroad company, being a large taxpayer, eventually pays no mean proportion of the 35 per cent. charged to the municipality.

In the design for the work, if the railroad is put under the highway, there should be not less than 18 feet headroom and 2 feet for floor of bridge. In Ohio there is a statute obliging an obstruction over a railroad track to be at least 21 feet above the top of rail, but I think this should be amended so as to give the Railroad Commissioner some discretion in the matter. Out on the open road, where trains run fast, and in the days before the nearly universal use of air brakes had greatly diminished the brakeman's duties in running from one car to another to set the brake, it might have been proper to require such headroom; but in these days, and in cities, where there is slow movement and where the locomotives and cars are equipped with air brakes, it does not seem necessary in all cases; and in fact other cities are adopting less headroom, and the Erie Railroad has been running for years in this city under bridges of very much less headroom, properly protected, without accident. I think the headroom should not be less than 18 feet, however; first, to allow for the future probable increase in height of locomotives and cars, which are constantly growing higher and higher, and also to allow a brakeman, if he is on top of a car, to sit down without being struck. If it were impressed on him that he could not stand, but might sit down, on going through a city, the liability to accident would be much reduced.

If the highway is put under the railroad there should be at least 13 feet headroom allowed, with 2 feet for floor of bridge at

highways where there is or may be an electric railroad, and 12 feet, with 2 feet for floor of bridge, at highways where no electric railway is likely to be built. This will not allow the use of a double-decked electric car, but I think it is not unreasonable to make this restriction. In fact, it must be remembered that the placing of the highway under the railroad immediately restricts materially the height of the vehicle and its load that can pass under the bridge, a restriction that, except for the trolley wires, which I hope are but temporary, is not encountered in any other part of the highway. The gorgeous band-wagon of the circus, for instance, or the floats of an industrial parade will have to take another route, whereas the railroad equipment is restricted just as much by other things, such as the heights of the top bracing on bridges or the cross-section of the tunnels, etc. This is one of the strong arguments in favor of placing the highway above the railroad.

The width of the highway should not be restricted unless under exceptional circumstances. It is true that London Bridge, with its enormous traffic, is but 56 feet wide, and that Chestnut Street Bridge, in Philadelphia, is but 40 feet wide; yet room seems to be necessary in this bustling life of ours, and the people are entitled to it. The grades on the highway approaches should be not more than 5 per cent. This is the grade used in Chicago, and many cities have steeper natural ones; certainly Cleveland has. I mention Chestnut Street Bridge because it is on one of the main thoroughfares between populations nearly twice as large as in Cleveland, and carries two street railroad tracks.

Nor should the width of the railroad be curtailed. It is hard to foresee what conditions may arise, and allowance must be made for future growth. If a highway becomes congested there are other highways, but to obtain other railroad tracks is another matter; always expensive, often impossible. The grades on the railroad should not be changed to make them a burden at the time or in the event of any possible future improvement to the railroad property, and for this reason great care must be taken in raising the elevation of the railroad tracks or in increasing their grade, as such change might involve a very serious burden on the property. There may be very little, if any, reserve power in a locomotive. It is usually loaded to its capacity; whereas, in the individual and electric car, within certain limits, there is ample reserve power, and the same is true of most horses. The railroad is an essential and admirable instrument in the growth and development of a city. It is a tool not to be abused and knocked about, but, like all other good tools, to be handled somewhat affectionately; to be kept always neat and clean and in thorough working order.

Other things being equal, it is certainly lighter, pleasanter, in every way better, to raise the highway. This may or may not involve the depression of the railroad tracks. If the tracks can remain as they are, well and good. In that case we have only to see that the structure and its supports are so constructed that they shall not interfere with the railroad and its operation; and, although the railroad authorities are seemingly actuated by selfish motives, it is pretty safe to conclude that they are fairly good guides to follow in these and in similar cases. If the tracks must be raised or lowered in order to avoid steep approaches or excessive property damage, it may be wise to lower them, the depth depending on circumstances. Through the residence district of a great city it may be well to lower the tracks the full distance required. An elevated track is an eyesore, noisy, extremely ugly and altogether horrid. Through the manufacturing districts of the same city it is better to elevate them, other things being equal; or, at most, to depress them but a few feet, so that existing manufactories can meet the changed conditions without excessive expenditure, and that adjoining unimproved property owners may not be deprived of the use of their property for the best purpose to which it can be put, as might be the case if the railroad tracks were depressed the full distance required. It is also true that, especially with railroad tracks, it is much easier and cheaper to raise them than to depress them.

The difficulties incident to the location of sewers, water mains, etc., in the depression of the tracks have no terrors for the engineer who is familiar with the work done by the cable car company in New York city, or with that proposed to be done by the Rapid Transit Company.

The question of damage to abutting property on the highway is always comparatively an important one where conditions are changed ever so slightly, and is always very thoroughly considered in cases of this kind; but it should not be given undue importance. Granted an equitable division, the cost is a secondary consideration, as the work is for all time and should be done in the best manner. Then again, the damage is only the cost of changing the buildings and other improvements to meet the changed conditions. The value of the land itself is rarely changed, for that depends upon the ease of access to and from a more or less crowded thoroughfare. For instance, the most valuable land in the world is at the intersection of Fleet street and the Strand in London, because of the crowds passing it. The corner of Broad and Wall streets, in New York, is possibly equally valuable, and especially in a raised highway this condition is not changed. What, then, is the damage to

the improvements? If, for instance, all the buildings at the corner of Euclid and Willson avenues and 200 feet each side were wiped out by fire in a night, the most sensational report would not put the loss on the buildings alone at any enormous figure. The insurance companies would certainly pay much less, and I do not doubt that the owners' sworn estimates of their value made to the tax assessor would show a very much further reduction from the amount the insurance companies would be called upon to pay; and again, the buildings in the aggregate would be damaged much less than half their value. Looked at in this way, the damage is reduced to a less formidable proposition. The trouble consists in arousing the antagonism of the owners themselves, who generally, and by the very nature of things, are men of influence and standing, and of much more power in the community than is the intangible stockholder of the railroad company, for instance; so that it is easy for them to obtain excessive judgments, especially when municipalities and corporations are to pay them. The process of awarding damages is human, therefore fallible. It might be better to appoint one or a few good men as commissioners to award them in place of the ordinary jury, as has been done in New York; but this may seem arbitrary to many accustomed to the old way.

In the actual performance of the work, that party who is in position to do any part of it best and most cheaply should do it. The municipality should settle the damages with abutting owners; and, as it can borrow money more cheaply than can the railroad companies, it might, if desired, lend its credit to the latter under well-considered conditions. The railroad companies might build part or the whole of the structure. The general principles being agreed upon, the details can easily be arranged.

As far as the maintenance is concerned, each party should maintain that part worn or used by it exclusively, and those parts where failure would render it liable in damages to others; where several parties use the same part, or where several would be liable, the expense should be divided proportionately.

DISCUSSION.

H. C. Thompson.—In the question of the elimination of grade crossings of steam railroads there are three parties concerned,—the city, the railroad and the manufacturers located on the line of the railroad,—each of whom have interests which should be carefully considered; the object being the harmonizing of these interests so that the expense of the improvement shall be equitably distributed.

The necessity of the improvement cannot be questioned. It grows every day, as the population and business of the city increase, and the longer it is postponed the greater will be the cost.

The crossings should be made above or below the grade of the railroad, as the conditions of each particular crossing are presented. The full width of the street should be maintained in all cases. The city has a moral right to demand this improvement, and all interested should be obliged to acquiesce in whatever arrangement is finally agreed upon.

The railroads were on the ground first, the city having grown to them and around them, thereby creating the demand for a change in the crossings.

It is fair to presume that when the railroads were built the construction followed the lines of economy with respect to the utility of the line as compared with the ground on which it was built, although possibly better results could have been attained at an increased outlay of first cost. Assuming this to be true, the expenditure of an additional sum would not destroy the present effectiveness or lessen the economy in operation as compared with what now obtains. This expenditure would be necessary to make the present gradients conform to the improved crossings, involving structures above, below and at the grade of the present roadbeds. The railroads have contributed to the growth of the city, and at the same time have profited by this growth, which has enhanced the value of their own property as well as that in the immediate vicinity.

The interests of the manufacturers and those of the railroad are to a great extent mutual, the manufacturer depending on the railroad for transportation, and the railroad deriving a great portion of its profit from the manufacturer. The manufacturer on the line of the railroad would have to conform to the new gradient of the railroad, because the conditions which obtain are more elastic, so far as he is concerned, than with the railroad, where the object is to preserve the present effectiveness with economy in operation.

It is to the interest of the city to encourage the manufacturer, because he contributes to the growth of the city; and, incidentally, the railroad enables the city to give this encouragement. The obvious conclusion is that all the interests involved are closely allied, and to a great extent mutual.

It would be premature at this time to say definitely how the expense should be divided. This could be arrived at intelligently only after a fair consideration of all the details of a perfected plan of operation, and, to the mind of the writer, the proper way to arrive at this end would be through a tribunal created expressly for this work, in which all the interests should be fairly represented. This tribunal should be clothed with power to determine on all questions which may arise, and should be composed of men skilled in this line of work, and able to give their time to a full consideration of the whole subject.

Association of Engineering Societies.

Vol. XXIII. JULY, 1899. No. 1.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, June 2, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Upon ballot, the following gentlemen were declared duly elected to associate membership: Alexander G. McAdie, U. S. Weather Bureau, and Erland Gjessing, of San Francisco.

The following applications were made and referred to the Executive Committee:

For members—Henry S. Dutton, architect, of San Francisco; proposed by G. W. Percy, H. C. Behr and Edw. F. Haas. Franklin C. Prindle, civil engineer, U. S. Navy, San Francisco; proposed by Otto von Geldern, G. W. Percy and Marsden Manson. Colonel S. M. Mansfield, corps of engineers, U. S. A.; proposed by Otto von Geldern, A. Ballantyne and C. E. Grunsky. Major W. H. Heuer, corps of engineers, U. S. A.; proposed by Hubert Vischer, A. Ballantyne and Otto von Geldern. Major C. E. L. B. Davis, corps of engineers, U. S. A.; proposed by Otto von Geldern, Hubert Vischer and A. Ballantyne. For associate—Geo. P. Wetmore, concrete builder, San Francisco; proposed by G. W. Percy, H. Barth and Otto von Geldern.

Mr. A. G. McAdie addressed the members on the subject of "Storm Structure," presenting an interesting description of the work and methods of the U. S. Weather Bureau, which was illustrated by fine lantern slides made for the purpose of the lecture.

The President expressed the thanks of the Society to Mr. McAdie and adjourned the meeting until the first Friday in August.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

A special meeting was held in the art room of the Butte Public Library, Butte, Montana, on July 8, 1899.

Meeting called to order by President Eugene Carroll at 8.30 p.m.; Mr. R. A. McArthur acting as Secretary *pro tem.*

Nine members and three visitors were present. The minutes of the preceding meeting in Helena were read and approved.

Messrs. John C. Patterson and Frederic J. Taylor were appointed a committee to prepare a memoir in honor of the late Henry C. Relf. It was found that less than one-half of the members had voted upon the amendment to the Constitution. Consequently the letter ballots were not opened and canvassed, but deferred to the next meeting.

Adjourned. A. S. HOVEY, *Secretary.*

Association of Engineering Societies.

Vol. XXIII. AUGUST, 1899. No. 2.

PROCEEDINGS.

Detroit Engineering Society.

The 40th regular meeting of the Society was held at the Hotel Ste. Claire, Friday, May 26, 1899; President W. J. Keep presiding.

The paper of the evening, "Deposits in the Pipe System of Detroit Water Works," was read by Mr. C. W. Hubbell, Civil Engineer to the Board of Water Commissioners, and discussed by several of the members present.

Adjourned. Henry Goldmark, *Secretary.*

The 41st regular meeting of the Society was held at the Hotel Ste. Claire, Friday, June 23, 1899.

Twenty-one members and guests were present. In the absence of all the officers of the Society, Prof. C. E. Greene was elected chairman of the meeting, and Mr. S. H. Woodard Secretary.

The name of John H. Galway was proposed for membership.

The paper of the evening was read by Alexander B. Raymond, upon "House Drainage," and discussed by Prof. Greene and Mr. Hubbell.

Adjourned.

Engineers' Club of Cincinnati.

107th Regular Meeting, Cincinnati, O., June 15, 1899.—Dinner was served at 6.15 p.m.; eighteen members and three visitors present.

The regular meeting was called to order at 7.10 p.m.; with President Hazard in the chair.

Minutes of the meeting of May 16 were read and approved.

The Secretary read a letter from Mr. W. B. Ruggles, dated Matanzas, Cuba, and addressed to Mr. R. L. Read, with which he sent a gavel for presentation to the club. The head of the gavel is made from wood taken from the Santa Christina Barracks at Matanzas, built some fifty years or more ago. On motion, the Secretary was directed to send to Mr. Ruggles the thanks of the Club for his kindly remembrance.

Dr. Thomas Evans, instructor in technical chemistry at the University of Cincinnati, read a paper on "Fuel Gas," devoted principally to discussions and descriptions of processes for the manufacture of fuel gas for use in metallurgical works.

Mr. L. E. Bogen read a paper under the title of "The Testing of Iron and Steel," in which he reviewed what has been accomplished in determining the quality of these metals by microscopical inspection.

Both papers were quite freely discussed.

Adjourned. J. F. Wilson, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, September 1, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

The following names were declared elected upon count of ballot:

Members—Paul W. Prutzman, chemist, San Francisco; Thos. Morrin, mechanical engineer, San Francisco. Associate member—Richard Keatinge, concrete builder, San Francisco.

A letter was read from the Southern Pacific Railroad Company, stating terms on which an excursion to Palo Alto could be conducted. It was referred to the Board of Directors, with power to act.

Thereupon, Mr. G. A. Wright, architect, read a paper on the subject of "The Quantity System of Inviting Bids from Contractors, and its Application to Engineering and Architectural Practice," a discussion of which was participated in by many of the members present.

Adjourned. C. E. Grunsky, *Acting Secretary.*

Association of Engineering Societies.

Vol. XXIII. **SEPTEMBER, 1899.** No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 20, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President C. Frank Allen in the chair. Sixty-seven members and visitors present.

The Secretary being absent, on motion of Professor Swain, Mr. E. W. Howe was appointed Secretary *pro tem.*

The record of the last meeting was read and approved.

The President appointed Mr. R. A. Hale a committee to distribute, receive and count the votes for new members. Messrs. Charles B. Breed, John H. Emigh and Orville J. Whitney were elected members of the Society, forty-two ballots having been cast for all the candidates.

Prof. George F. Swain, for the Committee on the Amendment of the By-laws, read the following report:

The committee appointed to draft the proposed change in Section 5 of the By-laws begs leave to recommend that paragraph 2 of Section 5 be amended so that it shall read as follows: "Of the candidates for any office, the one having the largest number of legal votes by the letter ballot shall be declared elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied, a majority of the votes cast being required to elect."

George F. Swain,
Alexis H. French, *Committee.*
Frederic P. Stearns,

On motion of Fred. Brooks, the report of the committee was accepted and the committee discharged. Mr. Brooks moved that the amendment be adopted, and it was voted that the amendment be printed in the notice of the next meeting. Action on the adoption of the amendment was postponed until the next meeting, as required by the By-laws.

Mr. H. A. Carson, for the committee, consisting of himself and Mr. Otis F. Clapp, read a memoir of Mr. Charles H. Swan.

The following letter was read from Mr. Charles A. Pearson, member of the Society:

Boston, Mass., September 20, 1899.

Prof. C. Frank Allen, President of the Boston Society of Civil Engineers:

Dear Sir:—It gives me pleasure in presenting through you to the Boston Society of Civil Engineers a portrait of the late Thomas Doane.

That Mr. Doane's personal qualities were appreciated by the Society is fully attested by the number of years which he served as its President, and also by his membership on important committees relating to the welfare of the Society.

In presenting this portrait I feel that it is but a fitting memorial in remembrance of one with whom I was intimately associated for thirty years.

His example was one worthy of following. His presence commanded respect, his opinions attention. His daily life was one of Christian love, purity and charity.

Yours very respectfully,

CHARLES A. PEARSON.

The portrait was accepted on behalf of the Society by the President with a few appropriate remarks. On motion of Prof. G. F. Swain, seconded by Mr. H. A. Carson, the thanks of the Society were voted to Mr. C. A. Pearson for the portrait of Mr. Doane.

President Allen then read a memoir of Mr. Doane, prepared by a committee consisting of Messrs. Desmond FitzGerald, C. Frank Allen and C. A. Pearson.

On motion of Mr. C. W. Sherman, it was voted that the Society tender its thanks to the Pennsylvania Steel Company, contractors for the Fort Point Channel Bridge, and to the Lowney Chocolate Company, for courtesies extended on the occasion of the excursion of July 19, and to Benj. W. Wells, Superintendent of Streets, Boston, the New England Sanitary Product Company and the Metropolitan Sewerage Commission, for courtesies extended on the occasion of the excursion of August 23.

Mr. H. A. Carson, Past-President of the Society, then gave a very interesting account of his recent visit to Egypt and Europe, and exhibited a large number of lantern views.

Adjourned at 10 P.M. E. W. HOWE, *Secretary pro tem.*

Charles Herbert Swan.—A Memoir.

BY HOWARD A. CARSON AND OTIS F. CLAPP, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 20, 1899.]

CHARLES HERBERT SWAN, who was a member of this Society for about seventeen years before his death, was born in Boston, August 17, 1842. Several of his immediate ancestors were prominent in this community. One of his great-grandfathers was a major in the Revolutionary War. On his father's side, Charles was related to the Tufts family, after whom Tufts College was named. Deacon James Loring, his grandfather on his mother's side, was founder of *The Watchman,* the well-known Baptist paper. His father, James G. Swan, formerly of Medford, is still living, in the State of Washington. His mother was Matilda Loring Swan, of Boston, who died in 1863. Charles was the older of two children. Miss Ellen M. Swan, his sister, lives in Boston.

In his youth he lived on Chapman place, near School street. He attended the Boston public schools, including the Brimmer and the Latin School, and, in March, 1859, entered the Lawrence Scientific School, from

which he was graduated in 1861. One of his classmates and friends at the Lawrence Scientific School, Roberdeau Buchanan, now an assistant in the Nautical Almanac Office, Washington, gives some incidents in regard to that portion of his life. Young Swan was remarkably quick mentally, and seldom failed to go through the demonstrations at the blackboard. The students were not marked and graded for their recitations, but he stood high in his studies. One day, after Professor Eustis had left the hall, Buchanan and Swan were engaged in their drawings, when the latter was overheard whistling the overture to "The Messiah," and later these friends and others often met to practice classical and other music, Swan playing the flute. Soon after taking their degrees of Bachelor of Science they both entered the office of C. L. Stevenson, civil engineer. The Civil War was then just beginning, and, as they had imbibed a number of military ideas from Professor Eustis, they determined to study fortifications together, and went through the course which was then pursued at West Point, making the customary drawings.

Later Mr. Stevenson was chief engineer on the construction of the Charlestown Water Works, and young Swan was engaged by him during its whole three years' progress. After the preliminary surveys were finished, he was assigned to the city division, in charge of laying the street mains. At the completion of the work a marble slab was erected at the pumping station in commemoration, and on this slab his name may be found among those of the other engineers, the commissioners, the Mayor, etc.

At a later time he was one of the engineers connected with the construction of the Salem Water Works, and he remained there until the fall of 1869, the last year of the time as acting chief engineer. He went from there to Providence, R. I., where he was one of the assistant engineers to J. Herbert Shedd, on water and sewerage works. While in Providence he was the first engineer to work out an abbreviation of the Kutter formula applicable to sewerage work, constructing a valuable set of sewer diagrams based upon that formula. He was specially connected with the numerous investigations entered into in the development of the plans for the water works and sewerage systems, and his services were valuable and highly appreciated.

He remained in Providence until 1881, except that he spent a part of 1874 and 1875 in Europe on account of his health. In 1880 he had serious eye trouble and was obliged to discontinue work for three years. He moved to Boston in 1881.

In 1884 he went to Europe with Samuel M. Gray, City Engineer of Providence, to study the sewerage systems of various European cities, and prepared the historical portion of the resulting report.

In 1886 he was employed, for about six or eight months, by Rudolph Hering, then Chief Engineer of the Chicago Water Supply and Drainage Commission, as a special assistant, to work out the problem of disposing of the sewage of the city of Chicago by filtration on land, and to estimate the cost thereof. Between the fall of 1887 and the spring of 1888 he was engaged, in making a study, for the Water Supply and Sewerage Committee of the Massachusetts State Board of Health, of the scheme of disposal of the sewage of the North Metropolitan Sewerage District by chemical precipitation.

He was teacher, for one term, at the Lawrence Scientific School during the absence of Professor Chaplin, in the spring of 1889, giving instruction in the strength of materials, in hydraulics, and in water supply and sanitary engineering.

In 1889 he was appointed one of the assistant engineers on the Metropolitan Sewerage System, and continued to be more or less actively connected with that work until the time of his death. He was specially engaged, in this connection, with all of the laborious and important investigations and studies as to the flow of sewage in the siphons and all other portions of the system and in investigations as to the stability of chimneys and various other structures.

From October, 1894, to September, 1897, he was an assistant engineer on the Boston subway, and made numerous studies for changes in sewers, pipes, etc. During a portion of this period he was also employed on the Metropolitan Sewerage System.

In the winter of 1897-1898 he made a report on a projected joint system of sewerage for Salem and Peabody. The question at issue was chiefly the apportionment of the cost between the two. Mr. Swan was employed by Salem.

From 1898 to 1899 he was again devoting his whole time to the Metropolitan Sewerage work, where he had charge of the special hydraulic studies and the preparation of the text of the engineering portion of the report for the high level gravity sewer for the relief of the Charles and Neponset River Valleys.

He became a member of the American Society of Civil Engineers in 1870, and of the Boston Society of Civil Engineers in 1882.

Soon after his twenty-first year he was received into the First Baptist Church of Boston. In 1872 he and Mrs. Swan joined the Roger Williams Free Baptist Church, of Providence. Not long after his removal to Boston, in 1881, he was received into the First Free Baptist Church, of which he was a member until his death. At the time of his death he was the President of the legal society managing the property of this church.

Those for whom and with whom he worked testify to his ability, his careful industry and the marked excellence of his work. He was very fond of books and had a good collection of his own, and he took great interest in systematically arranging and indexing them. His love of music and his skill in playing the flute have already been mentioned. This taste and skill continued through life and were the means of giving pleasure to many of his friends. During his later years he became much interested in photography, and was skilled in taking and developing photographs and in making transparencies. He was quiet and unobtrusive, but among those who knew him well he was an exceedingly entertaining and pleasant companion. The writers, and others who knew him intimately for years, cannot recall ever hearing him speak an uncharitable or unkind word.

June 30, 1870, he married Miss Carrie Cheney, a daughter of President O. B. Cheney, of Bates College, Lewiston, Maine. His widow and four sons survive him, the youngest being nineteen years of age. His domestic life was an ideal one. He was a loving husband and father.

Though not as robust as many men, and though at times suffering somewhat from a weakness of the eyes, he generally enjoyed good health, and there was every prospect that he would live and work for many years to come. On Tuesday, April 12, he visited the Metropolitan Sewerage office for the last time. The next day he was suffering somewhat from tonsillitis. On Sunday morning, April 16, he was found to be afflicted with malignant diphtheria. After some hours of apparent unconsciousness he died on Monday morning, April 17, 1899, aged nearly fifty-seven years.

Engineers' Club of St. Louis.

SEPTEMBER 20, 1899.—Meeting was called to order at 8.20 P.M.; President Colby presiding. Sixteen members and four visitors were present. The minutes of the 492d meeting were read and approved. The minutes of the 277th and 278th meetings of the Executive Committee were read. The application of Mr. O. J. Barwick having been recommended by the Executive Committee, he was balloted for and declared elected. The names of Messrs. E. B. Fay, E. A. Cordes, F. D. Beardslee, O. M. C. Bilhartz, Frank Ringer and W. J. Fogarty were proposed for membership.

The paper of the evening, entitled "Discipline," by Mr. Willard Beahan, was then read by the Secretary in the absence of the author.

In this paper the relations that should be maintained between employer or superintendent and employes were discussed, being divided under three heads: first, the right of the men to be heard; second, their right treatment; third, wages.

Under the first it was maintained that a hearing should always be given the men, whether they came as individuals, committee or society, and that by so doing the answer, whether acceding to their requests or not, if given with the reasons for it, would usually be gracefully accepted.

Under the second head, the necessity of seeing that the men's comfort and well-being be carefully looked after was set forth. Also that usually the head man should fare no better than the men if it is desired that they remain contented.

The question of wages was next considered and the adoption of a sliding scale of payment advocated, as in this way the most valuable men are gradually enabled to earn more and will thus be kept for long periods of time, to the benefit of their employers.

Mr. Beahan also went into the question of strikes, treating of their prevention and treatment after occurring.

The discussion following was participated in by Messrs. Bryan, Fish, Borden, Bouton, Colby and Von Ornum.

There being no further business, the meeting adjourned.

E. R. FISH, *Secretary.*

Montana Society of Engineers.

A MEETING of the Society was held in the Butte Public Library, Butte, Montana, on September 9, 1899. Meeting called to order at 8.30 P.M.; Mr. Francis W. Blackford in the chair, Mr. R. A. McArthur Secretary *pro tem.*

The applications for membership of Richard R. Vail and Albert Koberle were read and referred to the Trustees.

A vote of thanks was tendered Senator T. H. Carter for securing for the Society the Presidential messages and papers, consisting of a number of nicely bound volumes, containing all the messages of the Presidents.

Messrs. Page and Flood were appointed tellers to canvass the ballots on the proposed change of constitution, changing the headquarters of the Society from Helena to Butte. The vote was: Yes 56, no 6. Total vote cast 62. Whereupon the chair declared the amendment carried. Thus Butte becomes the headquarters of the Society.

A committee consisting of Messrs. Aug. Christian, John Gillie and F. J. Smith was appointed to nominate officers for the ensuing year.

Adjourned. A. S. HOVEY, *Secretary.*

Engineers' Club of Cincinnati.

108TH REGULAR MEETING, CINCINNATI, OHIO, SEPTEMBER 21, 1899.—Dinner was served at 6.20 P.M. Eighteen members and three visitors.

The regular meeting was called to order at 7.30; Vice-President Punshon in the chair.

Minutes of the meeting of June 15 were read and approved.

Application for active membership was received from Mr. Frank L. Fales, Assistant Engineer, Chief Engineer's Office, Board of Trustees, Commissioners of Water Works.

Mr. W. M. Venable, who was announced to read a paper on "Camp Engineering of Two Great Army Camps," described the work of the engineer corps, with which he was connected during the late war with Spain, at Camp Wikoff, at Montauk Point, N. Y., and at Camp Columbia, at Mariano, Cuba, in the establishment of these camps and in improving the sanitary conditions at them, more especially the former, which necessitated an immense amount of labor on account of the large number of troops to be provided for in the very short time allowed.

He exhibited several maps of the camps and a large number of photographs specially pertaining to the work, and others of points of interest taken during the campaign.

On motion, adjourned. J. F. WILSON, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXIII. OCTOBER, 1899. No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

494TH MEETING, OCTOBER 4, 1899.—The meeting was called to order at 8 P.M.; President Colby presiding. Sixteen members and three visitors were present. Messrs. Fogarty, Fay, Bilhartz, Ringer, Cordes and Beardslee, having been recommended for membership, were balloted for and all declared elected.

The paper of the evening, entitled "The Development of the Automatic Machine for Metal Working," was then read by Mr. H. S. Wilson. The probable incidents that led to the invention of the earliest and crudest form of machinery were given, together with short descriptions of the machines. The author then went on to give brief descriptions of old but more modern forms of automatic machines, showing how automatic machines of yesterday become the semi-automatic or non-automatic of to-day by reason of constant improvement.

The machines used for automatically making a large variety of articles were briefly described, and some of the wonderful results achieved with them noted.

Mr. McFarland exhibited some samples of automatic machine work.

There being no further business, the meeting adjourned.

E. R. FISH, *Secretary*.

495TH MEETING, OCTOBER 18, 1899.—The meeting was called to order at 8.15 P.M.; President Colby presiding. Thirty-two members and twelve visitors were present. The minutes of the 494th meeting were read and approved. The name of Mr. Jos. Boyer was proposed for membership. The paper of the evening, on "The Design and Construction of a Modern Central Station," was then read by Mr. H. H. Humphrey. A brief *résumé* of the legislation creating the underground conduit system for electric wires was given, and also the conditions influencing the organization of the Imperial Electric Light, Heat and Power Company. The conditions governing the design of the plant were fully entered into and afterward a general description given of the various parts of the equipment, both mechanical and electrical, and also of the conduit system and method of distribution. The paper was illustrated by lantern slides shown as referred to in paper.

The discussion following was participated in by Messrs. Wilson, Holman, Bryan, Reeves, Borden and Kinealy. There being no further business, the meeting adjourned.

E. R. FISH, *Secretary*.

Technical Society of the Pacific Coast.

Regular Meeting, October 6, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Mr. Stephen E. Kieffer, civil engineer, Sacramento, was elected to membership by regular ballot.

A letter was read from the Southern Pacific Company, stating rates at which a car may be had for the purpose of a Society excursion to Palo Alto and Greystone Quarry.

It was ordered that the Secretary circulate notices, requesting members to notify the Society of their willingness to attend this outing to visit the Memorial Arch now building on the Stanford University grounds, and to inspect the neighboring quarries; and that the date of the excursion be set for Saturday, October 14. (This date was subsequently postponed to October 21, and, on account of the inclemency of the weather, again postponed until October 28.)

Mr. Max Junghaendel, a visiting architect, discussed the plans and designs for the State University buildings, adopted by the late jury in the Phœbe Hearst competition, and criticized at length the various features of a design so vast and costly, which could not be realized under any of the ordinary conditions of time and adequate appropriations. This criticism was discussed by a number of visiting architects and engineers.

It was moved that the President and Secretary confer with Mr. J. Reihstein, and to ask of this gentleman the courtesy of permitting Mr. Junghaendel to take photographs of the various plans and drawings submitted to the jury by competing architects. Carried.

Adjourned. Otto von Geldern, *Secretary.*

Detroit Engineering Society.

The 43d regular meeting of the Detroit Engineering Society was held at the Hotel St. Claire, October 27, President Keep presiding. Minutes of the last meeting read and approved.

Mr. E. S. Reid was elected a member of the Society, and the name of Mr. F. A. Little was proposed for membership and referred to the Executive Committee. The paper of the evening was read by Mr. David Molitor, and was illustrated by blackboard sketches. The paper was discussed by Messrs. Williams and Dow. A vote of thanks was extended to the speaker of the evening. Attendance twenty-six. Meeting adjourned at 10.45 p.m.

T. H. Hinchman, Jr., *Secretary.*

Engineers' Club of Cincinnati.

109th Regular Meeting, Cincinnati, Ohio, October 19, 1899.—Dinner was served at 6.15 p.m. Fourteen members and one visitor present.

The regular meeting was called to order at 7.35 p.m.; Vice-President Punshon in the chair.

Minutes of the meeting of September 21 were read and approved.

On ballot being taken, Mr. Frank L. Fales was elected to active membership.

Mr. David Goldfogle read the paper for the evening, on "Some Details of Two Sewer Tunnels." The first part of the paper comprised a description of the construction of a brick sewer 11 feet in diameter, about 300 feet long, which was tunneled through the embankment supporting the Miami Canal at a point a short distance south of the Mitchell avenue aqueduct. At this point there existed an old stone culvert, semicircular in shape, from 5½ to 6 feet in height and about 12 feet in width at the bottom, which had been built at the time of the construction of the canal. This culvert had for its foundation a layer of hewn oak logs, about 10" x 12", laid close together and extending a short distance beyond the sides of the culvert. This old culvert was in very bad condition, the mortar having fallen from the joints, leaving large holes in the sides and top, necessitating great care in the construction of the new sewer, which was so located with reference to the old culvert that its bottom was about 8½ feet below the top of the old timber floor at the west end and about 5½ feet at the east end.

A wooden flume was constructed on top of the timber floor to carry the creek water during the construction of the lower half of the sewer. When this lower half had been completed for the entire length up to the timber floor, the old culvert being supported in the meantime by means of wooden struts and beams as the work progressed, the water was turned into it, the timber floor was cut away in sections and the upper half of the circular sewer built inside the old culvert, beginning at the middle and progressing each way. The space between the top of the new sewer and the inside of the old culvert was filled in solidly with brickwork. The total cost of the work to the contractor was about $22 per lineal foot of sewer.

The second part of the paper was devoted to a description of the method of constructing a tunnel for a 16-inch cast iron pipe sewer to replace a damaged 15-inch pipe sewer. The material encountered was blue shale and rock, and required blasting for its removal. The material was conveyed to the surface through shafts, in some of which brick manholes were built, the others being used simply for the purpose of facilitating construction and were filled up after the work was completed. The tunnel, after the pipe was laid, was filled with concrete to the center line of the pipe and the excavated material placed back on top of the pipe, completely filling the tunnel.

Illustrative maps and plans accompanied the paper, and after the reading of same a general discussion followed.

Mr. Elzner described briefly the septic system of sewage disposal.

Adjourned. J. F. Wilson, *Secretary.*

ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MEXICO.
GULF OF MEXICO
ATLANTIC OCEAN
PACIFIC O.
MONTANA
MINNEAPOLIS
ST. PAUL
ST. LOUIS
CINCINNATI
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W. VA.
VA.
MD.
KY.
TENN.
N.C.
S.C.
GA.
ALA.
MISS.
ARK.
LA.
TEX.
OKLA.
IND. TY.
N. MEX.
ARIZ.
FLA.
ME.
MASS.

Association of Engineering Societies.

Vol. XXIII. **NOVEMBER, 1899.** No. 5.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, November 3, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Mr. George Johnston, mechanical engineer, of San Francisco, applied for membership; proposed by G. W. Dickie, John Richards and G. W. Percy. The application was referred to the Board of Directors.

Mr. John Richards, Past-President, addressed the Society on the subject of "Patents and Monopoly," which was discussed at length by members present.

It was suggested by the author of the paper that a committee be appointed to inquire into and note the method of procedure followed by the U. S. Patent Office in the matter of determining the merits of a claim and granting the patent privileges. Also to compare these methods with those in vogue in foreign countries, and to report the results of these studies to the Society.

Mr. Dickie moved that a committee of three be appointed by the chair, and that the President be granted until the December meeting to select from the membership a suitable committee for this purpose. Carried.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Engineers' Society of Western New York.

The Engineers' Society of Western New York was delightfully entertained November 6, 1899, by a lecture, entitled "An Excursion to Egypt and Europe," delivered by Mr. Howard A. Carson, member Am. Soc. C. E., and a prominent engineer of Boston. The lecture was replete with interesting information, pleasingly illustrated by stereopticon views.

Boston Society of Civil Engineers.

Boston, Mass., October 18, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President C. Frank Allen in the chair. Fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. George Corrie Bartram, Frank Harrie Carter, William Lewis Clark and William Vaughan Polleys were elected members of the Society, twenty-five votes having been cast, all in the affirmative.

The amendment to By-law 5, which was reported at the last meeting, and which had been printed in the notice of this meeting, was then taken up. On motion of Mr. E. W. Howe, duly seconded, the amendment was adopted, twenty-three voting in the affirmative and one in the negative. As amended the second paragraph of By-law 5 reads as follows:

"Of the candidates for any office, the one having the largest number of legal votes by letter ballot shall be elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied; a majority of the votes cast being required to elect."

The President announced the deaths of three members of the Society. Sumner Hollingsworth died June 26, 1899; John H. Blake died July 5, 1899, and Samuel Nott died October 1, 1899. On motion of Mr. L. F. Rice, the President was requested to appoint committees to prepare memoirs. The following committees have been named by the President:

On Memoir of Mr. Hollingsworth, Messrs. J. R. Freeman and Chas. T. Main; on Memoir of Mr. Blake, Messrs. Fred. Brooks and Wm. B. Fuller, and on Memoir of Mr. Nott, Messrs. L. B. Bidwell and Edward Sawyer.

Mr. Walter B. Snow was then introduced and read an exceedingly interesting and valuable paper, entitled "Mechanical Draft for Steam Boilers." The paper was profusely illustrated with lantern views.

At the conclusion of the reading of the paper, on motion of Mr. F. P. Stearns, the thanks of the Society were voted to Mr. Snow.

Adjourned. S. EVERETT TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

497TH MEETING, NOVEMBER 15, 1899.—Meeting was called to order at 8.20 P.M.; President Colby presiding. Twenty-three members and six visitors were present. The minutes of the 496th meeting were read and approved. The minutes of the 281st meeting of the Executive Committee were read. It was moved and seconded, and the motion carried, that a Nominating Committee, to report at the following meeting, be elected. The result of the ballot was the election of Messrs. Russell, Holman, Bryan, Flad and Kinealy as a Nominating Committee.

The presentation of the 1898 Vol. of the Trans. of the Am. Inst. of Min. Engrs. by Col. E. D. Meier was announced, and a vote of thanks tendered the donor.

Prof. J. L. Van Ornum then read his paper on "The Volunteer Engineers in the War with Spain." A brief history of the formation of the engineer regiments was given and mention made of the numerous military duties and drills in which the regiments received thorough instruction. Besides the purely military features, the various engineering duties of these troops were explained, many of them being enumerated in detail. A short description of character of the actual work done by the Third Regiment while in Cuba was given. The paper was supplemented by a series of views, which were fully explained by the speaker.

The discussion was participated in by Messrs. Colby, Bryan, Kinealy, Nipher and Spencer. E. R. FISH, *Secretary.*

Montana Society of Engineers.

A MEETING of the Society was held in the art room of the Butte Public Library, Butte, Montana, on November 11, 1899.

Meeting called to order by President Eugene Carroll, at 8.30 P.M.; Mr. R. A. McArthur acting as Secretary *pro tem.*

The application for membership of Edmund B. McCormick, of Bozeman, Mont., was read and referred to the Trustees. The Secretary was instructed to send out letter ballots on the applications of R. R. Vail, Albert Koberle and Daniel J. McNally for membership.

Mr. Carroll, of the Transportation Committee, reported progress, satisfactory arrangements having been made with most of the railway companies for rates to the annual meeting, which occurs on the second Saturday in January. It was decided to hold the regular annual meeting of the Society at Bozeman, Mont.

The President appointed the Committee of Arrangements for the annual meeting as follows,—viz: Wm. H. Williams and Clayton H. Thorpe, both of Bozeman, and Frank L. Sizer, of Helena.

A letter from Vice-President M. S. Parker, relative to members from Utah, was referred to the annual meeting. The Secretary was instructed to call the December meeting for Butte, whereupon the Society adjourned.

A. S. HOVEY, *Secretary.*

Engineers' Club of Cincinnati.

110TH REGULAR MEETING. CINCINNATI, O., November 16, 1899.

Dinner was served at 6.20 P.M. Fourteen members present.

The regular meeting was called to order at 7.30 P.M., with Mr. Wm. C. Jewett in the chair.

Minutes of the meeting of October 19 were read and approved.

One application, for associate membership, was presented.

Mr. Alfred Petry read the paper for the evening, on "The Evansville Caisson." This caisson was built in 1896 and forms the bottom of the pump pit for the pumping station of the water works at Evansville, Ind. It is built of white oak and is circular in plan, with an outside batter, being a frustrum of a cone, 16 feet high, and with its top and bottom diameters 77 feet 6 inches and 80 feet 2 inches respectively. The roof is 8 feet thick, leaving a height of 8 feet for the working chamber.

The paper treated of the plan of construction of the caisson and the manner of sinking it to place, which was, for a part of the distance, by the use of compressed air, the apparatus for which was described in detail.

The caisson supports a stone masonry well, circular in shape, 53 feet inside diameter and 61 feet high, the wall of which is 12 feet 3 inches thick at the bottom, tapering to 4 feet at a point 17 feet from the top, and above that point continues the same thickness to the top. In this well are located the three pumping engines.

The paper was illustrated by a large sketch of the caisson and a number of photographic views at different stages of construction.

The reading of the paper was followed by a general discussion of the subject.

Adjourned. J. F. WILSON, *Secretary.*

Association of Engineering Societies.

Vol. XXIII. DECEMBER, 1899. No. 6.

PROCEEDINGS.

Engineers' Society of Western New York.

The fifth annual meeting of the Engineers' Society of Western New York was held in the rooms of the Ellicott Square Club on December 4, 1899.

Meeting called to order at 8 o'clock P.M.; Mr. Haven, chairman.

The following members and guests were present:

Messrs. March, Babcock, Tresise, Powell, Gorman, Dr. George Fell, Speyer, Pihl, Symons, Young, Mayor Diehl, Ricker, Haven, Eighmy, Buttolph, Knighton, Bassett, Houck, Kielland, Lewis, Clark, Rogers, Roberts, Fruauff, Rockwood, Diehl, C. F. Fell, Bardol, Knapp, Quintiss, Elliott, Wilson, Sornberger.

The minutes of the meeting of November 6th were read and approved.

The report of the Secretary, Mr. March, was read, received and filed.

REPORT OF THE SECRETARY.

Mr. President and Gentlemen:

Inasmuch as there were no annual reports presented a year ago, I wish to state briefly the work for 1898:

At the January meeting we were pleasingly entertained by Mr. E. C. Lufkin with a paper entitled "Pipe Lines."

February we were notified that the Society had been admitted as a member of the Association of Engineering Societies.

March, an instructive paper by Prof. R. C. Carpenter upon "Laboratory Experimental Work at Cornell University."

April, Major Symons presented the timely topic, "Coast Defenses and Fortifications," after which a light lunch was served at the rooms.

May, Mr. George W. Rafter gave an interesting paper on "The Run-Off of Niagara River."

June, report of the Reception Committee's work in welcoming the Convention of American Society of Mechanical Engineers, held at Niagara Falls.

Mr. W. S. Hunbert then delivered an exhaustive paper upon "Cement—Its Origin, History, Tests, Specifications, etc."

September, Mr. H. L. Noyes gave an interesting paper on "The Early History of Bridges."

October, Mr. T. Guilford Smith delivered a very comprehensive paper entitled "Important Works in Egypt."

The matter pertaining to the formation of a State Society looking toward effective legislation regarding the practice of engineering was laid on the table.

During October the American Society of Mining Engineers held one of its stated meetings in Buffalo, and our Society contributed largely to the entertainment of the convention, by various committees appointed to impart information, etc., and welcome the visitors, etc.

As there was no regular election of officers in December, 1898, the old officers retained offices during the year 1899.

At our regular March meeting we were favored by Mr. F. V. E. Bardol with an interesting talk upon "The Abatement of the Hamburg Canal Nuisance."

March 21, 1899, we held a special meeting to take action upon the preliminary plans of sites for the Pan-American Exposition, as the matter had been referred jointly to the Engineers' Society of Western New York and the Buffalo Chapter of Architects, by resolution of the directors of the Exposition Company.

At the special meeting held on June 15, the Secretary had the pleasure of reporting that nineteen new members had been elected.

The October meeting was full of enthusiasm and interest for the betterment of the Society.

At our November meeting we and lady friends were pleasingly entertained by Mr. Howard A. Carson, Mem. Am. Soc. C. E., a prominent engineer of Boston, who gave us a lecture entitled "An Excursion to Egypt and Europe," accompanied by stereopticon views.

This fifth annual meeting to-night will speak for itself, and I hope will live pleasantly in your memory for a long time.

The Society now numbers about fifty-four members.

Respectfully submitted,

H. T. March,
Secretary for 1898 and 1899.

Report of the Treasurer, Mr. Bassett, was read, received and filed.

REPORT OF THE TREASURER—1898-1899.

Cash on hand, December 15, 1897		$366.72
Received from Secretary to November 24, 1899		598.70
Total		$965.42
Disbursements of sundry kinds	$746.53	
Permanent fund	80.00	
Balance in bank	138.89	
		$965.42

George B. Bassett, *Treasurer.*

Messrs. Ricker and Roberts were appointed as tellers to canvass the vote of the Society.

After dinner the tellers reported that the following gentlemen were elected for the year 1900:

President—Mr. W. A. Haven.

Vice-Presidents—H. J. March, C. H. Tutton.

Secretary—George Diehl.

Treasurer—George R. Sikes.

Director—E. C. Lufkin.

Librarian—J. A. Knighton.

Mr. Haven declared the above-named officers duly elected for the ensuing year.

In the absence of Mr. Johnson, retiring President, Mr. Ricker, Past-President, delivered an address, in which he referred to certain features of the early history of the Society, and particularly to its entertainment of the American Society of Mechanical Engineers at Niagara Falls, an entertainment in which Mr. Johnson took an active part. Mr. Ricker emphasized the benefits which this Society can confer upon the engineers of Buffalo and of Western New York.

Mr. Haven, President-elect, expressed his appreciation of the honor conferred upon him by his election, and urged the importance of measures for making the members of the Society better acquainted with each other, of providing a more suitable place for meetings, and of having the proceedings published in the daily newspapers.

Hon. Conrad Diehl, Mayor of Buffalo, while claiming pre-eminence for his own profession of medicine, paid high tribute to the skill of engineers and to the importance of their work, calling attention to the bridge at Coblenz, the Mont Cenis Tunnel, the Niagara bridges, the Buffalo breakwater and the gorge road at Niagara as instances of such work.

Mr. Haven.—The Mayor has spoken to you about the nobleness of the medical profession, and that it is older than the engineering profession. During the coming year if I can get a draughtsman that knows how to make letters, I will give him something that was printed in 1645, entitled "The Description of a Complete Engineer," which I would like to have copied in pretty large letters and hung in the new rooms of the Society, showing that the engineering profession was known a good many years ago.

We would like to hear from some of the older engineers, and I will call upon Mr. Young to address us. (Applause.)

Mr. Young, referring to the Mayor's claims for the medical profession, called attention to the fact that the engineers were the pioneers of civilization, and that, while they could not rise superior to the necessity for medical science, that part of the work was often performed by a member of the engineer corps.

Mr. Haven.—I take pleasure now in introducing to you Major Symons, who, I think, is well known to you all. (Applause.)

Major Symons.—Mr. President and Gentlemen, the chairman of your committee has asked me to make a few remarks on the prominent features of the Government work in and about Buffalo, and I will endeavor to do so. It is rather a dry subject, but Mr. Ricker has provided something to wet it.

Very early in its history the people of Buffalo interested the general Government in their harbor, and throughout all the developments which have made this one of the great ports of the world, the general Government has been in active partnership with the people of Buffalo.

The first appropriation made by the general Government for the benefit of Buffalo harbor was one of $15,000, away back in 1826. Since then the amount expended by the Government for the benefit of Buffalo harbor has been about $5,000,000. It is not very difficult to imagine what a struggling little village Buffalo was at the time of the first appropriation; a few houses

down near the mouth of the creek, and a few hundred people gathered there, and woods and prairies all about. But the Erie Canal had just been completed and the hopes of the people were high, and there was no limit to their ambition. They had already, with money borrowed from the State, been endeavoring to improve the entrance to the harbor by dredging and building piers. The harbor inside the creek could be reached only with difficulty by the small sailing vessels of the period, and when in the creek these vessels were subject to damage from the lake rising under the influence of the Western winds and piling across the narrow neck of land separating the creek from the lake, and threatening to wash this neck away.

The earliest and most important features of the improvement work undertaken by the general Government were the construction of the piers at the entrance to the creek. It can readily be understood that without these piers the entrance must have been uncertain and dangerous, and especially so to the sailing craft of those early days. For many years a long struggle went on to build and maintain the south pier at the entrance channel. This pier, before the breakwater was built, was fully exposed to the terrific storms of Lake Erie, and it was repeatedly breached and in some instances carried away. When this happened, a little more money would be appropriated, and the pier would be patched up again and again. The history of this pier is almost pathetic as indicating the struggle made by the engineers, with little money and under many adverse circumstances, to maintain it against the fearful power of Lake Erie. To all of those who have been down to it and examined it the great strength which it was found necessary to give it is an indication of its importance and of this struggle.

The building and maintenance of the north pier was a much simpler problem, as it was protected against the worst storms by the south pier. There is no danger of this north pier getting away now, as it is being held down very securely by the Delaware and Lackawanna Railroad.

One of the earliest works undertaken by the general Government was to build a seawall to protect the neck of land lying between the lake and the inner creek, the harbor of Buffalo. This seawall is still in existence, although it is not now needed, having been supplanted by the outer breakwater, which takes its place as a barrier against the sea. Besides the good it did at the time, the construction of this seawall was a means of the city acquiring a heritage of very great value; this is the strip of land about 7000 feet long and 135 feet wide on which the seawall was built. By legislative action the city has been possessed of this strip of land for highway purposes, and I hope that it will soon take action to clear this off and convert it into a grand commercial highway running along the harbor front. I also hope that some means will be found to extend this grand future highway along the harbor front all the way to Stony Point. The existing Hamburg Turnpike would furnish the nucleus for such an extension, and I am going to ask you all as brother engineers to do everything in your power to bring this about, so that we can have a broad highway suitable for all purposes extending along the entire front of the new and great harbor of Buffalo.

The Mayor has brought this matter before the City Council and is trying with all his might to get this highway laid out and properly utilized, and the city of Buffalo is greatly indebted to Mayor Diehl for his stand on this question. But something besides the seawall and the entrance piers became necessary in the development of Buffalo harbor, and a breakwater was de-

signed to cover the entrance between the piers. Buffalo wanted this breakwater, and it got it. At first it was designed to be 2000 feet long; it was afterwards extended and extended until it finally reached a length of 7600 feet, about one and one-half miles. This was its length when I came to Buffalo about four years ago. When I came here in 1895 to take charge of the Government improvement works, there were two parties in the field, one which desired that the breakwater should not be extended farther, but with a return breakwater should be built connecting its southern end with the shore, thus making an outer harbor extending from the present harbor entrance about one and one-half miles to the south. The other party was in favor of extending the breakwater entirely through to Stony Point, about two and one-half miles farther. The latter party won, and the Government adopted the project and the work was started and is now well under way of building the breakwater from the southern end of the old breakwater entirely through to Stony Point. This work has been under way for about three years and will cost when completed about $2,000,000, and will in itself be the longest breakwater in the world, and if we consider it in connection with the old breakwater, the two together will make a breakwater defense against the seas at least 50 per cent. longer than any similar structure in the world.

About half of this breakwater at its southern end is to be timber crib structure, which does not differ in any marked degree from similar timber structures built here and elsewhere on the lakes. It does differ, however, in some of its constructive details, and it differs also from any other breakwater that has been built in the care and expense necessary to give it a good foundation. In this portion of the work the water in which it is situated is about 30 feet deep; the mud overlying the rock is from 30 to 40 feet deep, and through this mud there has been excavated an enormous trench reaching down to the underlying rock. This trench has a width of 60 feet on the bottom and an average depth of about 35 feet from the lake bottom to the rock. It was excavated by a dredge especially built for the purpose, and which I should have been very glad to have had you all see in operation. It has, however, finished its work and has been taken to the seacoast to do other work there. The trench thus excavated was filled with gravel dug out of the Niagara River down near the International Bridge. Upon the foundation so prepared the timber crib breakwater was built. It is expected that the part under water will endure practically forever, and that the part above water will last twenty to twenty-five years, and then will be replaced with a concrete superstructure.

About half of this new breakwater is composed entirely of imperishable materials, stone and gravel, no wood being used in it. This portion of the work is unique in a number of respects. It is the first stone breakwater of anything like its character to be built upon the Great Lakes and it is the first breakwater in the world, as far as I know, in which a hearting composing about one-half of its bulk is made of gravel. This gravel hearting saves about $600,000 in the cost of this portion of the breakwater, and renders it possible to complete the work within the amount which Congress was willing to allow. The cross-section of this stone breakwater was designed after a careful study, and its lines are practically the lines which would be developed by the action of storms upon an ordinary loose pile of stones. Taking this as a cross-section, we have added to its stability by covering it over from the top to a depth of 15 feet with huge stones carefully quarried out and care-

fully set in place. The contractors for the work were especially fortunate in getting a quarry from which they can get almost ideal stone for this purpose. This stone breakwater is unique in the way in which it is covered with a pavement of three enormous capping stones. No breakwater has even been built with natural stones of as great size and good quality and shape, and with these stones as carefully placed and bonded together as has this Buffalo breakwater, and I am confident that when it is finally completed and becomes known to engineers it will be regarded as one of the most monumental breakwater structures in the world.

In order that nothing should be left undone which the Government could do for Buffalo, the last session of Congress provided money for the building of a north breakwater to cover the shore area lying between the Bird Island pier and the Erie Basin, and this work has also been started, and we hope to finish it next year. This north breakwater is to be a timber crib substructure, and concrete and stone superstructure.

There are a good many other things which the Government has done and is constantly doing for the commerce of Buffalo, but I will not take up your time more than to mention in a very general way a few of them. There is the building and maintaining of the lighthouses marking the entrance to the harbor, and the entrance to Niagara River; there are five of these lighthouses right here; there are a number of buoys marking channels and shoals which are maintained by the Government; there is a large and constant expense for maintenance of the breakwater and pier structures, and the Government also at a considerable expense maintains a supervision over the navigable waters, looking out to see that they are not encroached upon in any wrongful manner.

There is a Governmental engineering project afoot in which the people of Buffalo, and particularly the engineers of Buffalo, must naturally take great interest. I allude to the proposed dam at the head of the Niagara River for the regulation of lake levels. The Deep Waterways Commission has been studying this problem for some time and I believe it is a work that is sure to come. The broad interests of lake commerce demand it, and we, here in Buffalo, must look at it from this broad viewpoint and at the same time see that the interests of Buffalo harbor and Niagara River are properly guarded. The proper designing of this dam, to hold back the waters at low stages of the lake and let them run off freely at high stages and at the same time provide for the navigation of the Niagara River, is a problem of the greatest interest, complexity, magnitude and importance.

The details of the plans of the Deep Waterways Commission have not yet been made public, and hence I do not feel at liberty to discuss them. When they do come they will certainly attract the attention of every engineer here.

I believe that it can safely be affirmed that there is no other country in the world which gives such liberal and efficient aid to its people in developing their commercial facilities and I hope that what little I have said may cause you all to feel as I do, that in all that relates to the interest and good of Buffalo, the Government is an active and efficient partner. (Applause.)

Mr. Haven.—As the officers of the United States Army are liable to be sent here, there and everywhere, it is hardly fair to ask them to become regular members of this Society; and I would ask some one to request me to recommend to the Executive Committee that Major Symons be made an honorary member of this Society. (Applause.)

Mr. Ricker.—Mr. President, I would move that you recommend to the Executive Committee that Major Symons be made an honorary member of this Society. Seconded by Mr. Bardol. Carried.

Mr. Ricker.—Mr. President, I would also move that you recommend to the Executive Committee that the Mayor of our city, the Hon. Conrad Diehl, be made an honorary member of our Society. Seconded by Mr. Bassett. Carried.

Mr. Rockwood, division engineer of the Erie Canal, urged the importance of measures for popularizing the Society and of increasing its library.

Mr. Ricker offered the following:

Resolved, That it is the sense of this Society that the Mayor's action of this day in recommending the appointment of a commission to investigate the matter of the seawall strip and to deal with the subject of this proposed great commercial highway along the water front be indorsed.

Seconded by Mr. Bassett and carried unanimously.

Mr. Bassett.—I would move that Major Symons' invitation to the Society to get out to view the breakwater at some time next summer be accepted now, and that the President be instructed to arrange with Major Symons for some date.

Mr. George Diehl.—I will second the motion. It is very courteous of Major Symons to invite us to inspect the breakwater. It is a very important and interesting piece of work.

Mr. Roberts.—I second the motion. Carried.

Mr. March.—The individual members of the Society have received a communication from the Director of the United States Geological Survey. giving a list of the topographical maps issued by that department, and I would move that the Secretary be directed to procure a set of the maps of New York State as issued by that department for the use of this Society, at whatever expense may be incurred in securing them.

Seconded by Mr. Roberts. Carried.

Interesting talks were given by Mr. Lewis on the street railway work in Buffalo, by Mr. Kielland on railway construction in South Africa, which was especially interesting at the present time, as Mr. Kielland was assistant engineer in the construction of the railroad that runs through Ladysmith. After short talks by various other gentlemen present the meeting at midnight adjourned.

G. C. Diehl, *Secretary.*

Engineers' Club of St. Louis.

498th Meeting, December 6, 1899.—Meeting was called to order at 8.25 p.m.; President Colby presiding. Twenty-two members and one visitor were present. The minutes of the 497th meeting were read and approved. The minutes of the 282d meeting of the Executive Committee were read. The Nominating Committee made its report with the following nominations:

For President—W. S. Chaplin.

Vice-President—E. J. Spencer.

Secretary—F. C. Bausch.

Treasurer—E. R. Fish.

Librarian—J. L. Van Ornum.

Directors—B. H. Colby, Wm. Bouton.

Board of Managers of Association of Engineering Societies—W. A. Layman. E. A. Hermann.

There being no further nominations, it was moved and seconded and the motion carried that nominations be closed.

The annual reports of the President and Secretary were read and on motions duly seconded were received and filed. The Treasurer's report was read by the Secretary, and on motion was referred to the Executive Committee.

On behalf of the Committees on Eads Monument and Smoke Prevention, Mr. Robert Moore made verbal reports.

Report of the Entertainment Committee was received and filed.

It was moved and seconded that the arrangements for the annual dinner be left to the Executive Committee. Motion carried.

Mr. Moore suggested that some action be taken toward filling out gaps in the files of the publications of the United States Engineers Department in the Club's Library.

Professor Nipher announced that he had nearly completed preparations for the measurement of wind pressures along the sides of the large University Building, which has a front of over 200 feet, and a depth of 45 feet. Simultaneous measurements will be made along the faces of the building, and the wind direction will be accurately determined at the instant of each pressure measurement. An invitation was extended to members and others who may be interested to at any time inspect the apparatus.

He also gave some explanation of the details of the apparatus, and some of the results of his experiments to calibrate the instruments.

The discussion was participated in by Messrs. Bryan, Colby, Kinealy and Moore. Adjourned. E. R. Fish, *Secretary*.

499th Meeting, December 20, 1899.—The annual dinner of the Club was held at the Mercantile Club at 7.30 P.M.; President Colby at the head of the table. Forty-one members and seven visitors were present. After the dinner was finished the officers for the new year were announced, as follows:

President—W. S. Chaplin.

Vice-President—E. J. Spencer.

Secretary—F. E. Bausch.

Treasurer—E. R. Fish.

Librarian—J. L. Van Ornum.

Directors—B. H. Colby, Wm. Bouton.

Members of Board of Managers of Association of Engineering Societies—W. A. Layman, E. A. Hermann.

Mr. Colby then surrendered the chair to the new President, who presided the rest of the evening.

Mr. Colby read an extremely interesting address on "Water Pollution," drawing a picture of the results of the emptying of Chicago's sewage into the Mississippi River, and showing the necessity for legislative action.

Mr. W. S. Chaplin made a short talk on "Engineering Ideals."

Mr. W. H. Bryan on the "Paris Exposition."

Capt. Edw. Burr on the "Engineer in Military Operations."

Mr. J. A. Ockerson on the "Father of Waters," and Mr. W. A. Layman on the "Engineering Panorama."

Following these a number of short speeches were made by several others.

E. R. Fish, *Secretary*.

Montana Society of Engineers.

A MEETING of the Society was held in the art room of the Butte Public Library, Butte, Mont., on December 9, 1899.

Meeting called to order by Vice-President Frank L. Sizer, at 8.30 P.M., Mr. R. A. McArthur acting as Secretary *pro tem.*

The application for membership of Edmund B. McCormick, of Bozeman, Mont., was read, and the Secretary instructed to send out the usual letter ballots.

Messrs. M. L. Macdonald and William Zaschke were appointed as tellers to canvass the ballots on membership, whereupon the chair declared Richard R. Vail and Albert Koberle to be duly elected members of the Society.

The report of the Nominating Committee of the officers for the ensuing year was read and on motion adopted, and the Secretary instructed to send out the usual letter ballots.

A preliminary report from the Committee on Arrangements for the thirteenth annual meeting, at Bozeman, Mont., was read and adopted.

Adjourned. A. S. HOVEY, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 1, 1899.—Held in the main hall of the Academy of Sciences, and called to order at 8.30 P.M., by Vice-President Hubert Vischer.

The minutes of the last regular meeting were read and approved.

Mr. George Johnston, mechanical engineer, of 326 Oak street, San Francisco, was elected to membership upon a count of ballots.

Mr. Harry Larkin, manufacturer, San Francisco, applied for associate membership. Proposed by G. W. Percy, E. T. Schild and Adolf Lietz.

It being in order to select a Nominating Committee for the purpose of choosing a list of officers for the ensuing year at this meeting, the following members were elected by acclamation: C. E. Grunsky, H. C. Behr, Adolf Lietz, Edward C. Jones and A. Ballantyne, who were instructed to prepare a ticket and report at the next regular meeting.

Mr. Max Junghaendel thereupon addressed the Society on the subject of "Hospital Arrangement and Construction," according to the most recent and approved practice, criticising therein a number of plans for the proposed city and county hospital, which were entered in competition by various local architects.

A short discussion followed, after which the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, DECEMBER 4, 1899.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Present, nine members and one visitor; President Estabrook presiding. Minutes of previous meeting read and approved. Letter of acknowledgment from Mrs. Archibald Johnson read and filed.

On motion of Mr. Powell, Mr. W. A. Truesdell was named to prepare a memorial to our late fellow-member, Archibald Johnson, deceased October 3, 1899.

Mr. A. W. Münster read a paper on the temporary bridge across the Mississippi River at Wabasha street, which paper he was requested to prepare for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Capt. A. O. Powell presented a diagram and explained results obtained with silica cement, which is being used in the construction of the United States Government lock and dam No. 2 at this point. Interesting discussions on lumber and cement occupied considerable time.

C. L. ANNAN, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., NOVEMBER 15, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President C. Frank Allen in the chair. Sixty-one members and visitors present.

The record of the last meeting was read and approved.

The President announced the death of William S. Whitwell, an honorary member and one of the founders of the Society; and on motion of Professor Swain the President was requested to appoint a committee to prepare a memoir. The committee named consists of Messrs. Francis Blake and E. W. Bowditch.

On motion of Mr. Metcalf, the thanks of the Society were voted to the Engineering Department of the city of Providence for courtesies extended this afternoon on the occasion of the visit to that city.

Prof. A. H. Sabin then read a very interesting paper entitled "Protective Coatings for Structural Metals." The paper was illustrated by an exhibit of 235 steel and aluminum plates which had been coated with various oils, varnish, paints and some special preparations, and had been immersed, part of them in fresh water and part in salt water, for about two years. A discussion followed the reading of the paper, in which Professor Sabin very kindly answered numerous questions with regard to paints and coating for metal work.

Mr. J. P. Snow gave a description of the method used by the Boston and Maine Railroad for cleaning its bridges in place by means of the sand-blast, which had proved very satisfactory.

After passing a vote of thanks to Professor Sabin for his interesting and instructive paper, the Society adjourned.

S. E. TINKHAM, *Secretary.*

Civil Engineers' Club of Cleveland.

REGULAR MEETING, DECEMBER 12.—President J. A. Smith in the chair. Present twenty-five members and twenty visitors.

Messrs. B. L. Green and E. E. Boalt appointed tellers to canvass ballots for new members. Charles F. Dutton elected an active member and L. B. Stouffer an associate member.

Resolutions upon the death of Mr. Clarence A. Carpenter were read and followed by appropriate remarks from several of the members.

Application for active membership by Mr. H. L. Olmstead was read and referred to letter ballot.

Mr. Bernard L. Green, member of the Club, then read a paper entitled "A Few Notes Regarding Grade Crossings and Their Treatment." A lively discussion followed, taken part in by Messrs. J. A. Smith, Augustus Mordecai, N. P. Bowler, Ambrose Swasey, A. H. Porter, Wm. H. Searles and H. C. Thompson.

Moved and carried, that the Club adjourn until December 26, for further discussion, and that Mr. Augustus Mordecai read a paper on that date.

Adjourned, 10 P.M.

ARTHUR A. SKEELS, *Secretary.*

SEMI-MONTHLY MEETING, DECEMBER 26.—President J. A. Smith in the chair. Present twenty-five members, seven visitors.

No business was transacted.

Mr. Augustus Mordecai, assistant chief engineer of Erie Railroad, and member of the Club, read a paper on "Grade Crossings." Discussion followed, taken part in by Messrs. H. C. Thompson, C. H. Haupt, E. E. Boalt, B. L. Green, James Ritchie, J. A. Smith an ' F. C. Osborn.

Adjourned at 10 P.M.

ARTHUR A. SKEELS, *Secretary.*

CANADA.
ASSOCIATION OF ENGINEERING SOCIETIES
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
KY.
W.VA.
MD.
VA.
N.C.
TENN.
S.C
GA.
ALA.
MISS.
ARK.
OKLA.
IND. TY.
ARIZ.
N. MEX.
TEX.
LA.
FLA.
ME.
MASS.
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC OCEAN